BRAKE OPERATION AND MANIPULATION IN GENERAL FREIGHT SERVICE

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Brake Operation and Manipulation in General Freight Service

With a Review of Some of the Causes and Conditions Which Produce Shocks and Break-in-Twos

BY

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BRAKE OPERATION AND MANIPULATION IN GENERAL FREIGHT SERVICE, WITH A REVIEW OF SOME OF THE CAUSES AND CONDITIONS WHICH PRODUCE SHOCKS AND BREAK-IN-TWOS.

By W. V. Turner

In the design of any brake equipment the starting point is always the weight of the vehicle to which the brake is to be applied. Given the weight of the vehicle, the problem then reduces simply to choosing the proper size brake cylinder which, with a predetermined maximum brake cylinder pressure and leverage ratio, will give the desired percentage of braking power. The process is clearly a simple one when applied to any given car and the method of procedure applied to cars of various weights will insure uniformity of results. However, it must necessarily follow that a brake equipment designed in this way for one car will not be proper for another car of a different weight from the first. The greater the difference in the weights of the cars, the greater will be the difference in the equipments required.

Underlying this proposition are fixed principles to which we must work if the best results are to be obtained, and once a set is determined upon for any design they must be continued as uniformity is fundamentally important. Of course, it must not be understood that departures from a proper basis will render a design inoperative, but it will not be as good as it should be in increasing proportion as it departs from the true starting point.

First: The thing to be fixed upon is the percentage of braking power permissible.

Second: The cylinder pressure to be used as a basis for calculation.

Third: Either the leverage or the size of the brake cylinder to be used.

(If the size of cylinder is determined upon, this will fix the leverage; if the leverage is determined upon, this will fix the size of cylinder.)

Regarding the first consideration namely, percentage of braking power, experience has confirmed that 70 per cent of the light weight of car on 60 pounds cylinder pressure (60 per cent on 50 pounds cylinder pressure) is the practically perfect basis for a freight car, and for reasons that are too obvious to require statement; but it should be added that reason confirms experience.

Regarding the second: This is important in two respects 1st, that it must be an obtainable pressure, 2nd, that it is universally applicable and adopted.

Regarding the third: This resolves itself into the question of how many times the cylinder power can be multiplied in a practical way, and is determined by the possible "lost motion" of the car, and the permissible increase of piston travel due to shoe wear, as the greater the number of times the cylinder value is multiplied, the more quickly will shoe wear lengthen the travel of the brake piston.

With the exception of the strength of materials, no other factors enter into the design, but those cited are vital and *must* be considered, and cannot be slurred over, nor can any one of them be omitted from the consideration and allowed to fix itself, for all others are so intimately related that they may be termed the one law of brake design.

It is often thought that an increase or decrease of the brake pipe pressure carried affects the design, but this is not the case, as this will only increase or decrease the braking power in an exact ratio to the change of pressure.

Assuming that sound principles and good judgment have been employed in designing the fixed apparatus of an air brake, namely, the triple valve, reservoir, brake cylinder, etc., and that these operate perfectly as individual units, (particularly in the laboratory where no moving vehicles are to be considered and, consequently, neither variations in power developed in the different cylinders, nor difference in time complicate the results of manipulation). It is necessary before discussing the actual manipulation of the brake to point out some of the factors which affect the operation and the manipulation of the brakes on the train as a whole. These may so change the original design as to make smooth operation and manipulation impossible. It appears to be thought by many that the brake being automatic in its action should also

be automatic in compensating for any lack of knowledge or for neglect on the part of those who use it, but this is not the case, and is as impossible of accomplishment as to run a locomotive without steam. The operation of the brake is according to fixed laws and conditions over *which the engineer of all men has the least control.*

As an elaboration of the principal factors involved would take up more time than has been at my disposal since being called upon to give this paper, and, undoubtedly, more than is at our disposal this evening, I cannot do more than state them and summarize the effects.

Percentage of Braking.

First: The percentage of braking power, so called. This has ususally been figured at 70 per cent on the light weight of the car, and this is certainly sufficient for the car when empty, but manifestly is reduced for the load in ratio to the difference in the weight of the car when empty and the car and load together. For example: if the braking power of a 40,000 pound car of 100,000 lbs. capacity is 70 per cent when empty, it will be less than 19 per cent when loaded, and this for emergency applications.

Pressure.

Second: The cylinder pressure obtained in the designs. This is supposed to be uniform for any given reduction and if the proper cylinder volume is maintained, it will be approximately so, but if the cylinder volume varies on the different vehicles, the pressure obtained will correspondingly vary, being less than normal for increase of volume and greater than normal for decrease of volume. Moreover, it is intended in the design that a low cylinder pressure be obtained for light reductions and a high cylinder pressure for heavy reductions, and this is the natural result, but lack of maintenance often brings about the opposite to this, for if the cylinder volume is small, a very high pressure will be obtained with comparatively light reduction, while a low cylinder pressure will be obtained for a heavy one in a cylinder having a long piston travel, and to avoid the results contingent upon this requires a knowledge of conditions and the exercise of a judgment possessed only by the few.

Piston Travel.

Third: Piston travel is such a factor in brake operation that its variation varies every operation of the brake as far as the developing power is concerned, for not only is the piston travel responsible for the variation in the cylinder pressure pointed out above, but it also varies the time required to obtain the braking power expected to be developed from a given brake pipe reduction. In other words, it is possible to obtain several times the braking power on one car as compared with another, due only to variation in piston travel, and it does not require a very vivid imagination to picture what this means to brake manipulation as far as producing shocks are concerned and it will also be seen that this is a factor over which the engineer has absolutely no control. Moreover, this variation in piston travel may be such as to entirely change the percentage of braking power expected to be obtained from the design for a given reduction, thus causing excessive braking power on some cars and too little on others, which is both prolific of shocks, due to surging, and of flat wheels, due to cars being dragged or bumped "off their feet."

Time.

Fourth: The time element is a very serious factor as affecting both the application and release of the brakes. In applying the brakes the starting takes place very quickly throughout a short train, therefore, there is no running in or out of slack, and, conquently, little or no shock, but in the long train, there is a considerable interval of time between the starting of the brakes on the head end and rear end of the train. In fact, the brakes on the head end may have fully applied for the reduction before they commence to apply on the rear end of the train, and unless great care and judgment is exercised to prevent bunching of the train, very serious results are likely to occur when the brakes apply at the rear and the reaction of the draft gear can stretch the train. Again, the rise of cylinder pressure is very different in the long train than in a short one, for the cylinder pressure cannot rise at any greater rate than the brake pipe pressure is being reduced and as this varies with the length of train, particularly at the rear end, it will be seen that the time factor must be considered with every brake manipulation.

The difference in and effect of time as affecting brake applications are graphically illustrated by Figs. 1 to 9, inclusive, of the Appendix, in which also some of the characteristics of curves are pointed out.

As to the release of the brakes, the time element also must be taken into account, for, obviously, there must be an interval of time between the release of the brakes at the head and rear end. This is certain even where the reduction has not been made below the equalizing point, but when the equalizing point has been passed, this difference is increased to such an extent that the engineer very often opens the throttle and accelerates the head end of the train while retardation is still taking place at the rear, and this even after he has thought he had allowed time enough. If it is important that the train be stretched before brakes are applied, it is doubly so before the brakes are released.

The difference in and effect of time as affecting the release of the brakes are graphically illustrated by Figs. 11 to 15, inclusive, of the Appendix, in which also some of the characteristics of the curves are pointed out.

Loads and Empties.

Fifth: Perhaps the most serious factor involved in freight train control is that arising from hauling loads and empties mixed, and this without considering any of the other factors enumerated above, but when considered in conjunction with them, the situation is certainly more serious than most people seem to think. As was pointed out, the braking power varies inversely, as the load and as the cars are now designed to carry about three times their weight, it will be seen that while the brake shoe pressure remains the same as for the light car the percentage of braking power, so called, to weight, has been reduced to one-fourth of what it was or is on the light car. If now we consider what must be the result of difference in cylinder pressure obtained and the time in which it is obtained on the empty and loaded car, it will be seen that with the present equipment, the only salvation against shocks and break-in-twos is (1st) to keep the train stretched—(2nd) to make at least initial reduction light in order that only a low power will be developed until the slack has adjusted itself—and (3rd) under

no circumstances to release the brakes, unless the slack condition of the train permits, until a stop be made. The usual custom is to haul the loads ahead and the empties behind and this is certainly more proper than hauling the empties ahead and the loads behind, for in case of a shock, with the empties behind, the result is at worst a parting of the train, while with the loads behind, the result is a buckling, which will be disastrous, particularly on parallel track roads. A better method of hauling loads and empties in the same train is to alternate them; thus avoiding great differences of braking power, due to variation in weight of train at any section of the train. This, however, involves switching, etc., which renders such a method impracticable. A better method still is to haul loads and empties in different trains. This again is impracticable on many roads. Thus, the proposition reduces to one of proper inspection and maintenance, instruction and discipline, which involves considerable intelligence and experience, or failing this, the proposition reduces to a cheerful acceptance of the consequences.

For a graphical illustration of conditions existing by reason of loads and empties, long and short piston travel and differences in "braking power" designs, see Fig. 16 of the Appendix.

It will be seen that all these factors are so intimately related that one involves the other to a considerable degree with the possible exception of loads and empties. Therefore, any neglect of one affects the other and conversely any great thought or consideration of the one improves the other. This relationship existing and time being limited, it will probably serve the purpose to consider two of these factors only at greater length, namely,

First: As to piston travel.

Second: As to braking power most desirable for freight cars under present operating conditions.

Piston Travel.

Piston travel may be divided into theoretical (under certain conditions Standing Travel closely approximates the theoretical travel) and actual travel (as under running conditions the travel differs from that obtained when the vehicle is standing). The theoretical travel is that which the brake cylinder piston is allowed to move in order to give proper shoe clearance, plus the movement due to the

necessary difference between the diameter of the pins and holes. Thus the theoretical travel equals the shoe clearance times the total leverage plus the travel due to difference in the diameter of the pins and holes.

The actual travel is comprised of the above plus that resulting from lost motion due to loose fitting brasses, play between boxes and pedestals, brake beam deflection and unusual temporary strains; in fact, to anything that produces or increases lost motion. I wish particularly to call attention to the practice of hanging brake beams from what amounts to a spring suspension, that is, to the car body or the truck frame above the springs. In such cases the shoes are drawn toward the rail by the pull of the wheel with consequent lengthening of piston travel. This is a most serious evil and where it exists the piston travel must be quite frequently adjusted to compensate for shoe wear, or the brake piston will strike the cylinder head; and in any case where excessive "false" travel is likely to develop a very low ratio of leverage should be employed.

The difference between the actual and the theoretical travel is erroneously called "false" travel, which, serious as it is, receives less consideration than any other thing in car design.

The theoretical piston travel is commonly called Standing Travel, and is defined as the distance the brake cylinder piston is forced outward in applying the brakes when the car *is not in motion*.

The actual piston travel is generally called the Running Travel and is defined as the distance the brake cylinder piston travels outward in applying the brakes when the car *is in motion*.

In studying the effects of piston travel, it must be remembered that in any application of the brakes, the brake cylinder pressure obtained depends upon two things; the ratio between the volumes of the cylinder and auxiliary reservoir, and the amount of brake pipe reduction. If the brake pipe pressure is reduced 10 pounds, the auxiliary reservoir will be reduced 10 pounds (slightly over); and the 10 pounds from the auxiliary reservoir going into the brake cylinder will create there a pressure depending on the volume of the cylinder and connecting passages as compared with that of the auxiliary reservoir. But the auxiliary reservoir volume does not change, so we may say that of the two, the brake cylinder volume alone is responsible for the pressure obtained. Now that volume depends on the amount of piston travel, if the

latter is short, the volume is small, and the 10 pounds auxiliary reservoir air will create a higher brake cylinder pressure than if the piston travel was longer and the cylinder volume thereby greater.

In order to show what a great difference the variation of piston travel makes in brake cylinder pressure and braking power, we show in Figs. 19 and 20 curves showing the theoretical variation for an 8-inch by 12-inch freight cylinder with standard cast iron auxiliary reservoir, with 6-inch, 8-inch and 10-inch piston travel, for different brake pipe reductions. Fig. 19 shows the relative increase or decrease of *cylinder pressure* as piston travel is decreased or increased. For example, with a 6-inch piston travel a 10 lb. reduction gives 34 lbs. cylinder pressure; while, with 8-inch 23 lbs. and for 10-inch 16 lbs. is obtained. Difference enough, it will be seen, to make those concerned take notice. Fig. 20 gives the percentage that the results in *braking power* obtained with the 6-inch piston travel are greater than those with the 8-inch travel; also the percentage less resulting with 10-inch travel as compared with the 8-inch travel. These curves show what great and damaging variations of cylinder pressure and braking power result with the initial brake pipe reductions. For example, with a 10-pound reduction, the braking power developed with a 6-inch travel is 45 per cent greater than with an 8-inch travel; also a 10-inch travel gives 38 per cent less than an 8-inch travel. In practice, the cylinder pressures realized are two or three pounds less than shown on the curves, while the braking power is considerably less, due to the lost motion, friction, and elasticity of the foundation brake gear. These losses make the conditions even worse than shown in Fig. 20.

We give in Table 1 the results that would be obtained in service with a 10-pound brake pipe reduction were there no losses of any kind. As a matter of fact the results actually obtained in service will be from two to three pounds lower, on account of leakage, etc. The effective braking power is that which would be delivered at the brake shoes for the cylinder pressure given, assuming that the leverage is designed for 60 per cent braking power at 50 pound pressure, this percentage being now recommended in freight service for steel cars, or wooden cars with steel underframes. In practice, 8-inch piston travel is usually taken as standard for freight service.

Table 1.

Piston Travel	Cylinder Pressure	Effective Braking Power	Comparison with 8-inch Travel
4″	52½ lbs.	63 %	130 % greater
5″	41 lbs.	49 %	78 % "
* 6″	33 lbs.	39½%	44 % "
7″	27½ lbs.	33 %	20 % "
* 8″	23 lbs.	27½%	—
9″	19 lbs.	23 %	16½ % less
*10″	16 lbs.	19 %	31 % "
11″	13 lbs.	15½%	44 % "
12″	11 lbs.	13 %	53 % "

*See Figs. 19 and 20.

Brake cylinder pressure and braking power developed with an 8-inch by 12-inch cylinder, having 50 cu. in. clearance, and standard cast iron auxiliary reservoir, with a 10-pound brake pipe reduction, and different piston travel, no losses whatever being considered, nominal braking power being 60 per cent on 50 lbs. cylinder pressure.

Tables similar to this could be made for any other brake pipe reduction, showing a variation similar in character but different in amount, the latter being greatest for small brake pipe reductions. As a result, it will be readily seen that if in a train, some brake cylinders have long piston travel and some short, a very uneven braking power will be developed for any brake pipe reduction, which will cause some cars to be retarded more than others, from which shocks and unnecessary strains on draw bars will result.

The proper piston travel is that which will develop approximately 50 pounds cylinder pressure when the auxiliary reservoir and brake cylinder become equalized from an initial auxiliary reservoir pressure of 70 pounds. This cylinder pressure (50 pounds) will then be the limit for a full service application, and should be obtained simultaneously on all cars. In Table 2 we show approximately the pressures at which the cylinder and auxiliary reservoir above mentioned will become equalized for different piston travels, and the brake pipe reduction required to give these equalizations.

Table 2.

Equalization pressures and brake pipe reductions necessary to give them for the brake cylinder and auxiliary reservoir given in Table 1, with initial auxiliary reservoir pressure of 70 lbs. and different piston travel.

8-inch by 12-inch Cylinder and Cast Iron Auxiliary Reservoir.

Piston Travel	Equalization Pressure	Brake Pipe Reduction
4″	59 lbs.	11 lbs.
5″	57 lbs.	13 lbs.
* 6″	55 lbs.	15 lbs.
7″	53½ lbs.	16½ lbs.
* 8″	51½ lbs.	18½ lbs.
9″	50 lbs.	20 lbs.
*10″	49 lbs.	21½ lbs.
11″	47 lbs.	23 lbs.
12″	46 lbs.	24 lbs.

*See Figs. 19 and 20.

Particular attention should be given, in this table, to the large variation in brake pipe reductions, the short piston travels requireing a smaller reduction and equalizing at a higher pressure than in the case of longer travels. To illustrate the detrimental effects of having such conditions in a train, let us suppose that two freight cars are coupled together, each having a light weight of 35,000 pounds, each equipped with an 8-inch cylinder and cast iron auxiliary reservoir, and the first having a piston travel of 11 inches and the second of 5 inches. It is plain that if a full service application is required on these two cars, a brake pipe reduction of sufficient amount must be made to equalize brake cylinder and auxiliary reservoir on both cars, which in this case would be 23 pounds, although 13 pounds would be sufficient for the second car. Consequently, 10 pounds of brake pipe air is wasted from the second car, and it obtains a cylinder pressure of 57 pounds, while the first car only obtains 47 pounds; moreover, the higher pressure on the second car is obtained in less than six-tenths of the time that the lower pressure is obtained on the first car. That is, there was 57 lbs. in the brake cylinder of the first car mentioned at the time that only 20 lbs. was in the cylinder of the second car. Let us suppose these two cars to be arranged to deliver 60 per

cent of braking power with 50 pounds cylinder pressure; then 57 pounds represents $68\frac{1}{2}$ per cent braking power, and 47 pounds represents $56\frac{1}{2}$. $68\frac{1}{2}$ per cent of 35,000 pounds is 24,000, and $56\frac{1}{2}$ per cent is 20,000 pounds. As a result, the stopping power of the second car is 4,000 pounds greater than on the first, and if we assume a speed of 20 m. p. h. and a coefficient of friction of 20% (which will be a fair average for this condition) a draw-bar pull of about 800 pounds is maintained between the two cars throughout the stop, or until the release of the brakes. If the release is made before coming to a stop, the brake pipe pressure need only be raised about $1\frac{1}{2}$ pounds to cause the first car brakes to start to release, while it must be raised about 12 pounds before the second car brakes start to release. The first car, having a comparatively low cylinder pressure, would probably fully release before the second car started to, resulting in a draw-bar pull for a short time proportional to the *entire braking power* of the second car, or, in this case, about 4,800 pounds. This belated release is often, but incorrectly, called "a slow release"; while that on the first car would be termed "a quick release"; as a matter of fact, if the two cylinders started to release at the same time from the same pressure, they would take an equal time to accomplish it. The fault lies, not in the brake apparatus, but in the improper adjustment of the foundation brake gear.

But still another condition might arise. Suppose a 14-pound brake pipe reduction should be made; the second car would equalize at 57 pounds, or $68\frac{1}{2}$ per cent—24,000 lbs. braking power, while the first car would only have a cylinder pressure of 24 pounds, the latter representing 29 per cent. braking power, or 10,000 pounds retarding effect. In this case, the draw-bar pull between the two cars during the application is about *2,800 pounds*, an amount which would be sufficient for the first car to bring the second, the latter loaded with 100,000 pounds of freight, from a standstill to 25 miles per hour in one minute.

From these considerations, it is clear that the best operation of the brakes can only be secured by maintaining a uniform piston travel upon all cars. The increase in the slack of brake rigging due to the wearing away of the brake shoes, must be constantly watched and taken up by means provided in the brake rigging, thereby maintaining the piston travel as nearly uniform as pos-

sible. By far the best means for accomplishing this is to install, in all cases where possible, an automatic slack adjuster, so called. Where this is not done, proper inspection and adjustment must be made at sufficiently frequent intervals to prevent any material increase in piston travel. As this inspection and adjustment has to be made while the car or train is standing, it must be remembered that running travel in steam road service is generally about $1\frac{1}{2}$ inches to 2 inches longer than standing travel, so that if an 8-inch running travel is desired, the standing travel should be adjusted to about 6 inches. If slack adjuster (shoe wear compensator) is used, attachment should be made to the 8-inch hole in cylinder.

Piston travel should never be altered to obtain a certain shoe clearance. This should be done by using brake cylinder of proper size, and through proper proportioning of the foundation brake gear. When inserting new shoes to replace those worn out, the brake rigging should be slacked off first, and the piston travel adjusted properly after the new shoes are in place. If, for any reason, it becomes necessary to change the piston travel, the auxiliary reservoir must also be changed, so as to keep the relative volumes of brake cylinder and auxiliary reservoir the same as before, thus insuring the same equalizing pressure and corresponding pressures for given brake pipe reductions.

The question as to whether the piston travel should be adjusted when the car is light or loaded makes necessary the following statement: Whenever the brake beam hangers are suspended from the solid part of the truck (which is now the best and most general practice), it is immaterial whether the car is light or loaded. If the hangers are attached to the car body, the adjustment must be changed whenever the car goes from light to load, or vice versa, for the following reasons: If the adjustment is done when the car is loaded, full braking power is available when the greatest weight is being handled, while there is a possibility, when the car is light and the shoes are raised making the shoe clearance less, that the resulting decrease in piston travel may raise the cylinder pressure sufficiently to slide the wheels. On the other hand, if the adjustment is made when the car is light, and the shoes in their uppermost position, wheel sliding is avoided, but there is danger that, when loaded, the increase of shoe clearance

and piston travel may result in greatly reducing the efficiency of the brake, and possibly no braking power at all for light deductions, which condition might cause runaways and disaster.

It is clear that a uniform piston travel is most desirable. If the piston travel be unnecessarily long, the brake cylinder pressure is thereby reduced and the efficiency of the brakes correspondingly impaired; in addition, a greater quantity of compressed air is consumed in brake applications than would otherwise be necessary, thereby entailing greater demands upon the air compressor, with correspondingly increased wear and tear. If the piston travel be too short, it is apt to be accompanied by dragging of the brake shoes upon the wheels while the brakes are released, and by too high a brake cylinder pressure, with an accompanying liability of sliding wheels, and rough and sudden stops when the brakes are applied. Besides, with a constantly varying piston travel, the engineer is never sure what retarding effect will follow any certain brake pipe reduction, and he will lose confidence in the brake; he can not become as expert in its manipulation as if the operation was more uniform, which if proper installation has been made, becomes largely a question of piston travel.

Curves illustrating the foregoing are given in Figs. 17 to 20, inclusive, of the Appendix, as well as a brief explanation of some of the characteristics.

Braking Power.

When the Automatic Air Brake was being put to a practical application, that is, used for controlling trains, it was found that the amount of cylinder pressure and braking power obtained for a given reduction were very important factors to be considered. After considerable experience and experiment it was proven, even for the comparatively short trains of those days, that the highest permissible braking power should not greatly exceed 1 per cent per pound of cylinder pressure (e. g., 70 per cent on 60 lbs. cylinder pressure) if trains were to be handled without shocks in ordinary service operation, and also that the cylinder pressures obtained should not exceed $3\frac{1}{4}$ lbs. absolute, per pound of brake pipe reduction; in other words, the auxiliary reservoir and brake cylinder should equalize at 50 lbs. from 70 lbs. initial; gage pressures (65 lbs. minus 15 for piston displacement). Accordingly a nominal brak-

ing power of something less than 60 per cent. on 50 lbs. cylinder pressure was fixed upon as the proper braking power for freight cars and an auxiliary reservoir employed so proportioned as to give a proper brake cylinder pressure per pound of brake pipe or auxiliary reservoir reduction and a brake pipe pressure of 70 lbs. was fixed upon as the desired pressure from which to obtain the maximum service brake cylinder pressure, namely, 50 lbs. These principles, of course, implied that "all air" trains were being handled for the reason that the length of train is an important factor in producing shocks, as if only a few air brake cars were being used, the brakes could not be much of a factor in stretching the train. However, it became the custom to use only a number of the brakes in long trains, generally on the loads ahead, the brakes on the empties not being used. Therefore, it was largely immaterial, under this condition of operation, what nominal braking power was adopted for the empty cars, as, obviously, if the brakes were not used, they could not stretch the train when being hauled behind loads. It was during this period that some roads increased the braking powers of freight cars from 70 to as high as 85 per cent. based on 60 lbs. cylinder pressure, and, of course, the result when hauling empties behind loads, particularly on a level, did not manifest itself as they were generally behind the cars on which the brakes were being used. When, however, it became the rule to operate "all air trains" quite another set of conditions were created, for not only were the brakes used on empties but, as far as the operation of the brakes was concerned, the length of trains was doubled, which is a serious factor, as the interval of time in brake application, particularly when combined with great difference of braking power at the two ends of the train, permits of the slack actions that are responsible for shocks. Thus the braking power of the empty cars became quite a factor in the handling of trains, for, obviously, the greater the braking power of the empties as compared with the load for the same cylinder pressure obtained from the medium reduction, the greater would be the retardation of the empties over the loads with consequent shocks and possible break-in-twos, particularly if the slack was bunched when the brakes were applied. Because of these things, a return was made to the old rule of 60 per cent nominal braking power based on 50 lbs. cylinder pressure, and even this would be regarded as

too high, if means were available for properly taking care of the car when loaded. If the braking power is made very great on the empty cars an approach will be made to the bad practice which was responsible for so many break-in-twos when employed, namely, hauling passenger cars with the brakes in use on the rear end of a freight train, or, what is perhaps even worse, permitting empty freight cars with short piston travel to be hauled behind loads.

Another thing that should be kept in mind is that a vital element in handling long trains without shock is the uniformity of the braking power both in time and amount, and as there is no such thing as uniformity in the amount of braking power when we consider loaded and empty cars with long and short piston travel and the various percentages of nominal braking power employed, etc., nor of *time* when we consider that this is varied by length of train and brake pipe leaks, etc., it is important that we prevent the ill effects of these variations to as great a degree as possible, which can best be done by insuring that the braking power obtained be as low as controlling the loaded car will permit, and its attainment stretched over such a period of time by range of brake pipe reduction, as will make sudden and severe strains unlikely. This is not only desirable but possible from the fact that all the braking power needed for controlling the loaded cars, even on grades, can be obtained by increasing the brake pipe pressure, which increases the ultimate braking power on all cars alike and without in any way interfering with the flexibility of the brake, i. e., without giving severe braking power for the initial brake pipe reduction, which it is important to avoid until the slack has had time to adjust itself. Moreover, this increase of brake pipe pressure does not widen the gap, already too great, between the ordinary service braking effort of the loaded and empty cars, while to increase the braking power on the empty cars does this to a serious degree. In other words, it does exactly opposite to what good engineering requires and what we are endeavoring to do, namely, bring about a uniformity of braking power on the empty and loaded cars.

In this connection, we might also mention that when it was found necessary to increase the stopping power of passenger trains it was not done by increasing percentage of braking power per pound of cylinder pressure, which, to obtain the increase desired, would have destroyed the flexibility of service features of the brake,

but, by increasing the pressure carried, thereby obtaining a cylinder pressure sufficiently high to give the desired increase of braking power. If this was the necessary procedure with passenger trains, how much more so with the long freight trains where the time and slack elements are of a much more variable and serious nature.

To compare the relative gain on empty and loaded cars by the proposed increase in nominal percentage of braking power (and considering service operation only, as the question of uniformity mentioned above need not be considered in emergency) we may take the following example:

PRESENT STANDARD.		PROPOSED STANDARD.
70% on 60 lbs.	Nominal Braking Power	70% on 50 lbs.
58.5% on 50 lbs.	This is equivalent to	85% on 60 lbs.
40,000 lbs.	Car—Light Weight	40,000 lbs.
140,000 lbs.	Car—Loaded Weight	140,000 lbs.
	FOR FULL SERVICE APPLICATION.	
	(50 lbs. Cylinder Pressure Obtained.)	
58.5%	Braking Power—Light Car	70%
16.7%	Braking Power—Loaded Car.	20%
41.8%	Difference between braking power on loads and empties.	50%
	FOR 10-POUND REDUCTION.	
	(20 lbs. Cylinder Pressure Obtained.)	
23.5%	Braking Power—Light Car	28%
6.7%	Braking Power—Loaded Car	8%
16.8%	Difference between Braking Power on loads and empties.	20%

By raising brake pipe pressure to 90 lbs. instead of increasing nominal braking power to 70% on 50 lbs., as proposed, the service operation is not affected. That is, for reductions up to that which will produce a brake cylinder pressure of 50 lbs., the braking power is the same as at present. The obtainable or reserve power of the brake is considerably increased, however, since the service equalization pressure is increased from 50 lbs. to 65 lbs. which would give

76% Braking Power—Light Car.
21.7% Braking Power—Loaded Car.
54.3% Difference between Braking Power on loads and empties.

From the above it is seen that if we increase the braking power from 70% on 60 lbs. to 70% on 50 lbs. (85% on 60 lbs. cylinder pressure), it will result in a net gain of 11.5% braking power on the light car and 3.3% on the loaded car for a full service application—the difference between the braking power on loads and empties being increased from 41.8% to 50%. If the desired increase is obtained by leaving the nominal braking power the same as at present standard (70% on 60 lbs.) and increasing the brake pipe pressure carried from 70 lbs. to 90 lbs., for a full service application, the gain on the light car is 17.5% and on the loaded car 5%. It should further be noted that up to 50% (the service equalization pressure when 70 lbs. brake pipe pressure is carried), there is no difference in the braking power obtained for a given cylinder pressure. That is, by raising the brake pipe pressure to 90 lbs. the brake remains the same for ordinary service reductions, but the ultimate braking effort is advanced by 17.5% on the light car and 5% on the loaded car. While this, of course, results in a wider difference, (54.3%) between the braking power on the loads and empties, it should be remembered that this is for 15 lbs. higher brake cylinder pressure than that for which this difference under the proposed standard is only 4.3% lower. Furthermore, this difference can only be attained by a full service reduction, during the progress of which the slack has an opportunity to adjust itself harmlessly, and while by increasing the leverage, the difference, as pointed out above, obtains on all partial as well as full service reductions. Again by increasing the brake pipe pressure, the gain is available on all cars alike, gives a large reserve power, during ordinary service applications of the brake and requires only an adjustment of the feed valve to accomplish the same, while the benefits of an increased nominal percentage of braking power are obtained only on those cars whose levers have been changed accordingly.

Fig. 16 (see Appendix) illustrates graphically the difference in braking power on loaded and empty cars. Taking for example a 10-pound reduction with 8-inch piston travel and 70% braking power, you will note that while the braking power on the loaded car is less than 10%, it is more than 30% on the empty car, or in other words, over three times as great. If, however, we assume a condition which frequently occurs in actual service; that is long (or relatively long) piston travel on the loaded cars ahead, and

short (or relatively short) piston travel on the empty cars behind, etc., it will be seen at once by the chart that the variation in braking power between the loaded and empty portions of the train is very much emphasized. For instance, with the 10-pound reduction as mentioned, we have a braking power on the loaded portion of about 8%, while assuming for the sake of illustration a piston travel of 6 inches on the empty cars, we have a braking power of about 47% or almost six times as great. If, on the other hand, the higher braking power of 85% is employed, and a 10-pound reduction is made with normal piston travel, the braking power on the loaded car is but a trifle over 10%, whereas that on the empty car has been raised to 37½%. From this it will be seen that the increase in percentage on the empty car is far greater than that on the loaded car, which latter in fact is but trifling. Consequently, the difference between the two is greatly exaggerated.

In the case of unequal piston travel cited above, if the braking power were raised to 85%, that of the loaded car when a 10-pound reduction is made would be increased only from 8% to 9%, whereas that of the empty car would be increased only from 47% to 56%, the undesired difference in braking power being thereby greatly aggravated.

Use of Release and Running Positions.

I feel a few words should also be said regarding the use of release and running positions on the brake valves, for it is here that the engineer may start trouble, for with the high pressures and large main reservoirs and the long trains of today, it is very easy to overcharge the head end of the train as compared with the rear and with a short train to over charge it throughout as compared with the adjustment of the feed valve. Many detrimental effects result from this, such as stuck brakes, flat wheels, cracked wheels, undesired quick action and where successive applications are made, as in grade work, in the brakes on the head cars doing practically all the work.

Another result which I would like to impress upon all is that a great many engineers think that because the gage shows that the pressure has risen very rapidly, and higher than the auxiliary reservoir pressure is intended to be, that the brakes are released and consequently open the throttle, while, as a matter of fact,

this is a condition that exists only on the first few cars of the train, the pressure of the rear not having yet increased sufficiently to force the triple piston to release position. In fact, twenty-five cars back from the engine, it cannot be told from a gage whether the handle is in release or running position. With modern engine equipment, the brake valve should not be held in release position more than 15 seconds when releasing brakes is the object. The exceptions to this rule are when charging up a train, or under some conditions of grade work.

An inspection of Figs. 21 to 27, inclusive, of the Appendix, accompanied by a perusal of the explanation will demonstrate the importance of this phase of the subject.

It will be seen from what I have said that brake manipulation and operation in freight service involves more than the judgment of the engineer in moving the brake valve handle back and forth. In fact, much more is dependent upon the condition of the train and the brakes than upon the manipulation by the engineer. Nay, more, it will be seen that the conditions may often make judgment impossible and insure shocks and break-in-twos in spite of it. Comprehension and application should come *down* from the officials to the engineer and instruction and discipline *up* to the engineer through the car men and trainmen. Until this is done, we are trying to cure our troubles by pecking away at the effect instead of what is more logical and reasonable, namely, dealing with the cause.

In concluding this subject, I desire to mention some of the changed operating conditions which have made much more difficult the control of freight trains, then analyze a proposed change or two expected to improve conditions, after which offer a few suggestions, the adoption of which will greatly reduce shocks and break-in-twos.

First: Heavy and more powerful locomotives (often two of these used to a train)—increasing the difficulty of starting trains without shock—making long and heavy trains possible, this, self-evidently, making the control more difficult—also severe strains, are set up when the brakes are released on these heavy weights before it is possible to obtain the release of the brakes on the rear; also with freight trains bunching the slack (because the brakes on the engine, if in good order, will produce more retardation than

those of the cars), then when the brakes take hold on the cars at the rear (generally empties), or, if for any other reason, the slack runs out, shocks are likely to result. With passenger trains, the reverse is true, as the cars are always being retarded more than the engine, and therefore the train is stretched.

Second: Cars of greater capacity, therefore, greater weight, and this without corresponding increase of the light weight, thus reducing the braking power when loaded to a greater extent than with the older cars. This condition creates a greater difference in braking power between the forward and rear end of the train when we have loads ahead and empties behind.

Third: Different percentages of braking power, some roads using 70 per cent and others as high as 90 per cent of the light weight; others, again, intermediate percentages. These things all tend to make the braking power unequal (and, of course, the longer the train, the worse it will be, because the time element "cuts quite a figure"); so much so, that if we got together a combination of long trains—loads ahead—empties behind—(and if these empties have short piston travel, the situation is aggravated to a remarkable degree), high percentage of braking power—slow speed and brake application (particularly if made by an engineer who does not nor has not taken these things into consideration),—a break-in-two is to be expected.

Fourth: Different sizes of brake cylinders. And this has more effect than most people think. For one reason, because the total leverage will be varied by the weight of the car and size of cylinder, thus the piston travel, so important a factor with light or medium brake pipe reductions, will vary greatly for the same shoe wear—this is self-evident with cars under-cylindered or when equipped with brakes with which the service and emergency cylinder pressures are the same.

Fifth: Varying brake pipe pressure: This changes the time element, often resulting in a heavier or a lighter application than was intended.

Sixth: Varying brake pipe volume: Thus modifying the time of application and release; and this far beyond direct proportion. The effect of this will be seen when it is borne in mind that men who have been coupling up and handling a fixed and limited number of cars—therefore, an approximately constant volume—often

fail to release the rear brakes of a long train before opening the throttle, or take into consideration the length of time it takes to get the air out or back into the brake system of long trains.

Seventh: "All air trains," and from a train handling standpoint this is one of the most important factors, as no matter what the make-up of the train, the brakes must be cut in within certain limits, therefore, if the train is so made up that excessive and damaging retardation takes place at the rear, the scheme of cutting out every other brake cannot be resorted to, as was done on some roads until recently, where "all air trains" were being handled. (By "all air trains" is meant that the brake pipe is charged with air from the engine to the rear of caboose.) Not only this, but it is plain that more knowledge, greater skill and constant thought is required on the part of all concerned to deal with conditions so variable as those involved in the make-up and the means of controlling the trains today. In other words, the human equation is more of a factor than ever before. This, I am happy to say, is beginning to be realized, and soon, I hope, many will be convinced that more consideration must be given to the condition under which the brake operates, if the results due to lack of consideration are to be avoided, for it is a fact that there are proper and improper conditions for the brake as for other mechanical devices, and there is more to it than simply attaching it to a car.

Eighth: In this connection, it may be well to mention that the many different styles of draft rigging have quite a bearing on the matter of shocks in trains; those possessing the greatest dissipating power with no recoil being, in my opinion, very necessary to meet the conditions of today, as the brakes and engineers can hardly be expected to compensate for all the changes that have taken place.

Ninth: Other things might be mentioned and elaborated upon —such as a greater number of parallel tracks, more yards and the frequency of trains, but I think the foregoing will help keep in mind the complexity of the problem when what follows is being considered.

Many schemes are proposed to alleviate these troubles; good, bad and indifferent, most of them bad because they do not touch the root of the matter. In one detail they are nearly alike, viz., in beginning with the engineer, while here is where they should end.

The brake is a good servant, but a bad master, and it becomes rebellious when contending with impossible conditions and is somewhat sensitive to neglect.

A quasi-plausible scheme actually put in effect on a great railroad for a time (a short time only for the remedy was worse than the disease) and recently considered by another, was to reduce the pressure carried in the brake system to 50 or 55 pounds. There were three advantages to be gained by this, so it was said:

(1) That the braking power would not be so great for a service reduction and, therefore, that the severity of the shocks and break-in-twos would be reduced. This, however, would only hold true for heavy reductions, as, for instance, a 10-pound reduction would give the same cylinder pressure whether the brake pipe pressure be 70 lbs. or 55 lbs., other things being equal. And, as the shocks and break-in-twos will usually occur, if at all, by the time a 10-pound reduction has been made, it is plain that reducing the pressure would be of no help in this case; this, of course, applies to service applications.

(2) That undesired quick-action will occur less frequently. This, however, will not necessarily follow, as, while undesired quick action due to friction caused by pressure on the slide valve may be reduced, yet undesired quick action due to slowness of reduction will be increased. Therefore, the gain in one direction is offset by the loss in the other, and I believe more than offset. Moreover, there should be no undesired quick action with 70 lbs. brake pipe pressure carried, and if there is, it can be corrected much more effectively by keeping the apparatus in a workable condition than by reducing the efficiency of the brake; which means in the last analysis its abandonment.

(3) That in the event *of undesired* quick action the maximum braking power possible to obtain with the lower pressure will be less than with the higher; and here we have the only reason that is even plausible. But even this can only be granted when it is assumed that we are compelled to choose between two evils, viz., (1) air brakes improperly maintained and operated and, (2) a lower efficiency of the brake both in service and emergency applications. It is self-evident that the brake will be less efficient with an emergency application, but it may be necessary to point out that for service applications not only would the braking power

of an equalized application be less, but the reserve for partial applications would be much less in one case than in the other. In other words, where with 55 lbs. brake pipe pressure the operator would have to use a reduction that would produce equalization to control his train and therefore eliminate any reserve and make a stop impossible; on the other hand, with the higher pressure the same reduction would give him the same train control and leave a reserve braking power equal to that already obtained, thereby making a stop possible if called for.

The above, I believe, covers all the arguments that can be advanced in favor of the lower pressure, and the analysis shows that they are by no means sound and certainly not sufficiently decisive to warrant the change. It may be said (but certainly not advanced as a reason) that 55 lbs. will control an empty train more effectively than 70 lbs. will a loaded train, and this may be granted but it does not follow from this that the empty train with 70 lbs. has any surplus of control, and until this is proven, it would not appear wise to lower the braking power of the empty train simply because the loaded train is under-braked.

Moreover, *these other things* should be considered; that it will be difficult to secure the change of pressure when changing an engine from an empty train to a loaded train, and vice versa, and no doubt you would often find the loaded train carrying 55 lbs. and the empty train 70 lbs. of brake pipe pressure, and particularly I believe you would find that once the engineers were led to believe that 55 lbs. was a panacea for their troubles, it would be difficult to prevent their carrying the lower pressure when they should carry the higher—especially where the train is made up of loads and empties; also it should be considered whether it is trains composed of all empties that are breaking in two in the great majority of cases. I am of the opinion that you would find that it is where a long string of empties are behind loads that this occurs; if this is so, even a consideration of 55 lbs. cannot be permitted.

Another scheme actually put in practice by some roads is to put up the percentage of braking power on empty cars. This is done ostensibly to increase the braking power for the cars when loaded. There *may* be some excuse for roads doing this who have heavy grades to negotiate, for perhaps they consider it a choice between

putting up with break-in-twos or risking run-aways on the grades, or perhaps they have empties one way and loads the other, as for example the D. I. & R. 125 per cent, or perhaps again they are wise and do not haul empties and loads in the same train, knowing that by increasing the braking power on the empties they have made this more riskly and impracticable than ever before. However, the other roads have to handle the cars, so somebody gets the effect.

As it is unequal braking power that is responsible for shocks, anything that tends to this is pertinent to the question of train control. Therefore, the analysis of this practice, on pages 15 to 21, is in order. It must be understood that as some look at it, it is a choice of two evils—braking power too low for grades, or too high for empties behind loads—but if they increase the braking power some one is going to have greater difficulty in smoothly controlling some classes of trains.

In this connection I may also point out that general recommendations and instructions apply to general conditions; particular and specific conditions requiring and permitting considerable modification of such general recommendations to suit the case, and it is only with an intimate knowledge of and with particular reference to such cases that one can be specific.

There are other schemes no more effective or practical than this, their chief virtue being a *desire* to find some way to reduce shocks and break-in-twos. As these undoubtedly arise from unequal braking power in different parts of the train, which may be temporary, as, for instance, the brakes applying more quickly or with higher cylinder pressure at the head end of the train than at the rear; or permanently, as, for instance, when there are loads ahead and empties with short piston travel at the rear, I will point out that shocks or break-in-twos may be greatly reduced by:

(1) Forbidding the use of the straight air brake of the engine to bunch the slack of the train before applying the automatic brake. I am aware that you will quote Westinghouse Instruction Books against this rule, but these instructions, as well as many others, were given to suit conditions very different from those of today. It is a self-evident fact that when conditions change, old rules and instructions become obsolete, or must be changed to suit the new conditions. A slight review of the instruction regarding the

use of straight air to bunch the slack gently, may be sufficient to demonstrate this. This instruction given when only part "air trains" were the rule, was necessary, as if the brakes were applied on the braked cars before the slack was in from the unbraked cars behind the shock was sometimes equal to a collision. Now, if the slack is bunched with an "all air train," particularly with empties at the rear, the running out of the slack, as the brakes take hold at the rear, often results in a break-in-two and certainly in a shock which is damaging to both equipment and lading.

Personally, I doubt the advisability of using straight air at all for train control, as so much judgment and care is required to use it when and where it will do good and not harm. I mean now for making stops or slow-downs—for if it is applied heavily, a collision is often the result—if applied and released and the throttle opened, while the cars are bunching or still bunched at the rear, a break-in-two is in order. Of course, there are critical speeds and conditions when damage is more likely than at other times. Straight air on the engine is of great value when used at the proper time and place, but it was not intended to take the place of the automatic brake in controlling trains, nor to be used because *unfair conditions* impair the efficiency of the automatic brake.

(2) By placing loads at the head of the train and shortening the piston travel, and the empties behind and lengthening the piston travel,—bringing about a greater difference in cylinder pressure for graduating applications and thereby securing greater equality of braking power between loads and empties; at the same time the emergency pressure will be only slightly altered.

(3) Alternating loads and empties.

(4) Applying the brakes before the slack is bunched as, for instance, before the steam is shut off.

(5) Instructing engineers not to use emergency applications unless actual emergency exists; not, for instance, to consider every switch, water-tank, or coal shute as an emergency zone and apply the brakes accordingly.

(6) Not to use heavy initial service reductions, unless speed is low and stop intended.

(7) Do whatever is necessary and possible to secure uniform application of brakes.

(8) Do all possible to insure that it is the engineer that is controlling the application of the brakes and not the brake pipe leakage, and in general that the brakes are maintained in such condition that the anticipated operation is possible and obtained. Give the engineer a chance.

(9) Avoid, if possible, applying or releasing brakes when passing over "Hog-backs" or round curves.

(10) Avoid releasing the brakes before the brakes have ceased to apply during a reduction.

(11) Avoid, whenever possible, applying the brakes again after a release, while the brake pipe pressure is higher at the head end than at the rear, in other words, equilibrium of pressure should be established throughout the train, as otherwise the head brakes will apply and those at the rear will not—therefore, the cars may be bunched and if the brakes at the next reduction take hold, this in conjunction with the recoil of springs will produce severe shocks.

(12) Avoid releasing brakes at speeds below ten miles per hour unless the locomotive is equipped with "ET" or the forward cars with K" triple valves, as otherwise brakes releasing at the head end permit the retardation still existing at the rear to stretch the train—sometimes beyond the strength of the car connections.

(13) Avoid, whenever possible, having too many cars at the rear which are levered for a high braking power, as for instance, cars (of which there are many in service) upon which the braking power is calculated at 90% on 60 lbs. cylinder pressure—it is obvious that this aggravates the already existing inequality of braking power between loads and empties and is in effect the same as attaching so many passenger cars to the rear end of a freight train, which no one who expected smooth operation would do, unless the brakes on these rear cars were alternately cut out.

(14) Locate the places where accidents of the kind under consideration most often occur and advise extra precautions, for, undoubtedly, you will find that there are certain track or signal conditions, which, in conjunction with an application or release of the brakes (to say nothing of the starting of trains), tend to produce shocks, and this, added to the already numerous factors tending in the same direction, often result in a "break-in-two." I think you will find that a number of your men are cognizant of this fact and have these places pretty well "spotted" and are governed accord-

ingly and, therefore, do not have near the trouble that some others do who either cannot reason back from effect to cause or are careless. To these latter a little information and advice may mean a close approach to the results obtained by others who learn by experience. I think I can illustrate what I mean by this paragraph by calling to your mind how necessary it is that an engineer, new to a division, become acquainted with the track, etc., before the best results can be expected. In other words, other things being equal, his proficiency depends largely upon his knowing the condition under which he operates.

(15) At speeds of over 20 miles per hour make a light preliminary reduction, followed by continuous heavy reductions when speed is reduced to, say, 8 miles per hour and stop intended. At low speeds, when stop is intended, make a continuous full reduction. The reason for this is to keep the slack bunched as the brake will naturally be applying with greater power on the head end than at the rear, therefore, tending to keep a steady push toward the engine.

(16) If slow-down only is desired, it is better to make a light reduction, far enough back, than a heavy one to accomplish the same result in less distance; in the former case, when the release is made (even if at slow speed) there should not be braking power enough to cause shock, while in the latter case the reverse is true.

(17) Enforce the rule that with long trains the engine must be cut off from the train whenever an accurate stop is imperative, as for coal and water, and insist that, after again coupling to the train that sufficient time be allowed for the brakes to release before trying to start the train.

(18) A terminal inspection that will discover and send to the repair track all cars with defects particularly of draft gear, that are likely to cause trouble on the road. There is no doubt that a great number of break-in-twos are due to defective brakes and draft gear being allowed to leave terminals, and it is hardly a question whether it is wiser to take chances than to adopt a safer method. Of course it is only a matter of time before the inevitable happens, but each thinks it possible that the car will reach the next terminal. Plainly, as long as chances are taken in these matters, even the best of care on the part of those operating the train on the road, cannot prevent a great many break-in-twos.

As stated, the difference in braking power is held to be the cause of shocks, etc., and the foregoing include at once the reason why and how it can, in a large measure, be overcome and uniformity more closely approached. It is plain that to do this involves both effort, expense and inconvenience, but my railroad experience taught me this was unavoidable and to be expected in railroad operation, and I may say that in the matter under consideration, what has been outlined permits of a choice between what *exists* and *what we desire*, to determine which the benefits versus the cost will be the governing consideration.

In conclusion, it may be well to state that the cause of break-in-twos may be traced to the method of handling the brakes—to the condition and class of draft gear and brake equipment—to the make-up of the train and the kind of train service—it being understood that the human equation is a qualifying factor at all times. All these causes taken singly or collectively are such at times as to make a break-in-two difficult if not impossible to avoid.

"Break-in-twos" are caused by greater braking power at the rear than at the forward part of the train. This class of break-in-two often causes much inconvenience and some loss, but as it is a separation and not a collision the danger of serious accident is not great, unless following trains are too close.

"Buckling" is caused by greater braking power at the forward end of the train than at the rear. This occurrence not only means inconvenience and loss but that the danger of serious accident to both the train to which it occurs and to others of either direction is very great, as the cars may be scattered over the different tracks.

I have gone into this part of the subject somewhat fully, if not completely, because I should at least do so sufficiently, to permit of your weighing both sides of the question.

The number of things mentioned show the complexity of the problem and many may say that no one can take all these things into consideration. This may be so, but they exist and must be dealt with as a condition and not a theory, and in proportion as they are taken into consideration will improvement be made, and, what is also important, the responsibility will be placed where it belongs, which is the first step toward desired results.

It will be seen that there are four elements involved in every brake operation, namely: 1st, time: 2nd, amount of reduction or

change of pressure in the brake pipe: 3rd, amount of cylinder pressure obtained, and, 4th, percentage of braking power. Only one of these is fixed, viz.—the percentage of braking power. That is, a given pressure in the cylinder gives a certain braking power; all the rest are variable. For instance, the time required to reduce the brake pipe pressure a certain amount is varied by increasing or decreasing the length of the train because this changes the volume of air in the brake pipe. The amount of reduction required to obtain a given cylinder pressure is varied by the ratio of the reservoir to the brake cylinder and the cylinder pressure obtained from a given decrease in reservoir pressure is varied by the ratio of the brake cylinder to the reservoir, which ratio is varied by an increase or decrease of piston travel, as this in effect increases or decreases the size of the brake cylinder. Plainly, then, all these elements must be kept in mind when considering any problem involving train control and it is only by knowing the relationship existing between the different elements that the cause of the results obtained can be deduced.

The control of trains has become a much more complicated problem than heretofore, much knowledge of all the conditions involved is necessary, and the best talent available will be taxed to the limit to get the most economical efficiency, and yet, strange as it may seem, these things are realized only by the few.

The air brake has advanced in the past year or two from being considered chiefly a safety appliance that was required by law to be applied, to an absolute necessity in the handling of freight and passenger trains, and its operation must be properly understood to make it a dividend earning asset.

THE PRESIDENT: The speaker wishes to know if you prefer to ask questions now, or if you want to ask the questions as he throws the slides upon the screen.

A J. COTA (C. B. & Q): I believe it would be the best plan to have him put on the slides first.

MR. TURNER: In the paper read it was pointed out, among other things, that the percentage of braking power, the cylinder pressures obtained, the effect of varying piston travel, and the time element were very important factors and modify both the operation and the manipulation of the brake. These elements and their effects can be shown by curves and charts even better than in actual operation and a number of these are referred to in the text.

The majority of these curves and charts are traced from indicator cards. The indicators used are essentially similar to steam cylinder indicators, but in addition have an electrical attachment connected to a clock which registers the time—the time of the commencement of the experiment and its duration being registered simultaneously throughout the whole train, consequently, we not only have the time for the whole experiment, but also the differences in time between any similar operation throughout the train. In other words, we know the time of any given operation at any part of the train. Other of these curves are plotted from calculations, as they are simply questions of proportion, and one of their values is that they serve to show how important is the maintaining of the proper proportions and that in so far as they fail from what is proper the operation is adversely affected.

THE PRESIDENT: We would be glad to have you ask such questions as you may have in mind and we will give Mr. Turner an opportunity to reply to them before the minutes are published.

MR. W. E. SYMONS (C. G. W. Ry.): Owing to the lateness of the hour, and the fact that Mr. Turner has talked for a couple of hours, giving us a very interesting paper, and I might say, a highly scientific lecture, I think it would be an imposition to ask any questions here tonight that would involve further discussion. There are one or two points which occurred to me that I would like to mention, with the suggestion that Mr. Turner be furnished a copy of the questions asked (and on which I would like permission to amplify), so that he can reply by letter in his closure.

Question 1. In the earlier part of Mr. Turner's paper he mentioned the fact that the braking efficiency of cars varied from 100 per cent to as low as 44 per cent, or, we might say, a range of difference in efficiency of 56 per cent, and while the details were not given as to just all of the causes that might contribute to this, yet it might occur to some that the different makes of brakes and different types of the same make, might have a little something to do with this condition.

It was also suggested by the author, that the switching of cars to certain parts of the train would minimize this trouble to a great extent, and while this is true, yet under present operating conditions this plan may be considered impossible, and of course it is necessarily incumbent upon the motive power officers to take care

of the brake equipment in such a manner, that no matter what distribution is made of this diversity of types and conditions we should get practically what might be called average results, and if there is anything that Mr. Turner can tell us in his closure that would throw additional light on the best thing to do to the brakes now on our cars (aside from suggesting the switching of the cars around), that would be a very good thing for the motive power department and mechanical officers to have to work upon.

Question 2. Another point in connection with that same question was, where the piston travel varied, causing a wide range of difference in cylinder pressure. My recollection is the author said that a great deal of trouble resulted from this inequality of piston travel, and the consequent difference in pressure of the brake cylinder was largely due to the faulty location or arrangement of the foundation of the brakes. Now, if I am right in that, I want to ask the author if he would kindly explain, if that was the fault of the railway companies in applying brakes to cars that they build, or in making repairs, or is it a fault in the designs furnished by the air brake builders? I am assuming that all brakes are applied according to prints furnished by the Air Brake people, therefore, if the foundation of the brake is faulty, or in any manner affects their operation or the proper equalization of pressure, then the fault may be due to the design, and not chargeable to the Railroad Companies.

Question 3. Another question has occurred to me in connection with this matter that I do not think the author mentioned. With some systems of levers, or brake arrangements, the brake rod lies pretty well out to the side of the car, in fact, on some trucks with side bearings spaced 60″ radius, the brake rod lies next to the side bearings, and sometimes on the outside, with the upper end of the brake lever almost in line with the side bearings, and in rounding curve, with this brake rod on outside of the curve, I would like to ask if this will have the effect of shortening the rod, particularly on rounding a very sharp curve? If that is true, is it then not a fact that this might exert some influence on the derailment of a car. Assuming that curve elevation was arranged for a high rate of speed, in which case the centrifugal force would result in the equilibrium of the car body, but the train moved at a slow rate of speed around the curve, allowing the cars to lean heavy on the inside of the curve, and bearing hard on the inside side bearing, if

that was the case, and the brake rod was on the outside, and this condition resulted in shortening the rod thus placing more strain on it than when the car was on the straight track, would it not have the effect of assisting the leading outside flange of the truck wheel in climbing the rail. Would not this combination assist somewhat in a derailment which otherwise might not occur if the train was going at a higher rate of speed, or was on a straight track?

Question 4. Another point in connection with friction draft gears, which possess, as we all admit, many good points, but just what effect they would have, or what percentage of effect in the elimination of damage to cars or contents, the author did not state, and I would be glad if he would elaborate a little on that, if he so disposed, particularly on the type of draft gear, spring or friction that is considered most efficient in service and economical in repairs.

In the matter of sending cars to the rip track when they need repairs, that point is a very good one, and while of course it would result in a highly improved condition of the brakes, I rather suspect if that were followed out strictly, we would have to stop a great many important trains with high grade freight when they really could go forward, and while I think the instruction or advice given to railways is very good, yet I am inclined to think the railroads would hardly be able to carry this out, so long as the present method of handling cars is in vogue that we now tolerate in switching yards, which results in much damage to draft gear in general. Still, if the author feels that recommendation can be carried out, I would be very glad if he would elaborate on that point.

There are a number of other points that are quite important, but I feel, owing to the lateness of the hour I have mentioned all I should, and in justice to the author, I would not ask him to reply to them this evening.

PROF. L. E. ENDSLEY (Purdue University): I appreciate the difficulty experienced by the author in preparing a paper like this in so short a time, and I move you, Mr. President, that the Club extend a vote of thanks to Mr. Turner for this very excellent paper.

MR. TURNER, *Answer No.* 1: Replying to the first question asked by Mr. Symons, I may say that the great differences in braking power may come from each or a combination of several causes, namely: difference between empty and loaded weight of cars, different standards of braking power on different railroads, and some-

times even by the same railroads, variations in piston travel, brake cylinder leakage, length of train, and the use of different makes of brakes, in which the auxiliary reservoir and brake cylinder proportions are different and in some of which the service amd emergency brake cylinder pressures are the same. All of these factors are dealt with at considerable length in the body of the paper and various suggestions as to their elimination in some cases and a minimizing of their detrimental effects in others are given, and finally it is stated that the officials have the choice of correcting some of these evils as they do others in connection with railroad management, or of letting them exist, which, however, will not be done when it is realized how profitable an air brake in good working order may be made, particularly as this will eliminate from the loss side of the account the cause of troubles and damage always inseparable from mechanical devices not in proper working order. I respectfully refer those who require a more complete answer to Mr. Symons' question to those pages of the paper covering this subject and to the curves and charts in the appendix.

Answer No. 2: In many cases the variation in cylinder pressure on different cars, or on the same car at different times, for the same amount of brake pipe reduction is due to improper foundation brake gear design, making it impossible to obtain or maintain the piston travel required by the auxiliary reservoir volume (which, it may be needless to say, is the same for all brake cylinders of the same diameter in steam railroad practice), which necessarily means that the stroke of the piston must be uniform if the same and proper cylinder pressure is to be obtained. In this connection I may say that very few designs for foundation brake gear are furnished by the Westinghouse Air Brake Company—in many cases the general practice being to build the car without any particular reference to the foundation brake gear and then put it on as may best or easiest be done, nor was this so important when the brake was looked upon as a mere safety device, but since it (the brake) is now essential to control trains in ordinary every day operation, it is also essential that greater consideration be given to foundation brake gear design, installation and general maintenance. However, the chief causes of differences in cylinder pressure are neglect to adjust piston travel for brake shoe wear and the hanging of the brake beams on the car body side of the springs, which permits the piston travel to change

according to whether the car is empty or loaded, and also very materially increases the piston travel by the creeping of the shoes toward the rail when the brakes are applied, due to pull of the wheel on the shoe. This latter is one of the worst forms of false travel. This question is also covered more in detail in the text of the paper and by the curves and charts.

Answer No. 3: As it was not the purpose of the writer of the paper to go quite so far as we are carried by this question, an answer is not exactly called for, still I might be pardoned for saying that inferentially this bears out the statements made in the answer to Question No. 2, that foundation brake gear designs are sometimes bad.

Another reason for not answering this question is that the answer is contained in the question, for Mr. Symons has so well outlined the stresses set up by such an installation that there can be no doubt of the bad effect of such a design of the brake, or that, under certain conditions, the tendency is to derail the car.

Answer No. 4: The writer mentioned draft gear in one paragraph of the paper and then only to call attention to the fact that in some cases the cause of a break-in-two could be found in the draft gear, and, wherever the draft gear is too weak for the stresses to which it may be subjected, or is weakened by usage, it is likely to give way under conditions where it would not occur if of proper strength or design. Moreover, break-in-twos often occur where a draft gear is employed that absorbs energy instead of dissipating it, as is the case with spring gear, and this will be all the more appreciated when it is considered that the recoil is given back in the form of a jerk instead of a buff—a jerk being much more likely to part a train than a buff.

As the draft gear situation is before us in many papers, pamphlets and discussions, the writer thought it was sufficient to merely call attention to draft gear as one of the elements involved in the general question, and, therefore, to avoid repetition respectfully refers those interested to literature dealing with draft gear problems and designs.

As to sending cars to the repair track, I may say that nine-tenths of the work required to eliminate air brake troubles and obtain proper efficiency can be done without sending cars to the repair shop. Instructions to inspectors and carmen as to what to do in the way of stopping brake pipe, brake cylinder and retaining valve

leaks and adjusting piston travel and insistence upon its being done is one of the chief requirements, and all this work can be done with the train in the yard. True, it will take some little time, but the delays will be nothing compared with those now occurring on the road and, of course, the damage to equipment and lading will be eliminated proportionately. Next, engineers should be taught that there is some difference between handling a long train with all the brakes cut in and a short train; also a difference in handling all empties, all loads or mixed trains; also that conditions are different now that we have "all air" trains that when only the brake on a few cars were used and the remainder not. In fact, the manipulation required now, in many instances, is the reverse of what it used to be. For example, the old rule was to bunch the slack before applying the brakes—the present rule is to avoid this. Again, with small pumps and small main reservoirs and low pressures, the full release position could be used with impunity, but with large compressors, large main reservoirs and the high pressures of today (which have a reason for their existence), the full release position must be handled with considerable thought of the consequences.

Again, with the brakes used only on a few cars, and these loads, and the slack of the cars behind the air cars bunched by use of straight air on the engine, or other means, a *heavy* reduction was not only permissible, but proper, but now with the air operative throughout the train and empties behind, a heavy reduction is likely to break the train in two, because of the disparity in retarding force between the loaded and empty cars. In other words, the initial reduction now made should be light in order that the cylinder pressure obtained on the empty cars should not create such retardation at the rear as would break the train in two. It will be seen that none of these things involve sending cars to the "rip" track. Of course, there are some cases where this is necessary and it should be done, but this is not so universally necessary as is generally thought. In fact, I believe it is the impression that this is necessary, which is responsible for the failure to make the slight repairs and compensations required for wear and tear between terminals. The defects are generally small individually, but the potentiality for trouble in an aggregation of these is great. We are not limited to two horns of the dilemma as implied in the interrogation of whether or not we shall send cars to the "rip" track, for it is not

a question whether we send all or none, as we may send only those that require such repairs as cannot rapidly and quickly be made in the yard, repairing such others where they stand.

In conclusion, I may say that it was not the writer's intention to usurp the prerogative of the railroad official and say what can or what cannot be done, nor how things should be done, but to point out what is required to efficiently control freight trains and what is responsible for failure to get such control—the pleasure of devising the means and method being left to those concerned, as well as the choice of having things as they are, or as they ought to be.

Mr. Turner: I should like to say one word relative to this evening, and that is, that I thank those who have listened to the paper, which was rather technical in places. There were a great many points brought up in connection with the work required to make it clear, for an evening like this, a great deal of elaboration, therefore I feel that the paper will be much more beneficial when printed than it has been tonight. I know when I was studying those points over from the practical point of view, that it took me more time to figure out all there was in it; it did not take very much time to put it on paper, but it takes a lot of time to figure out all that is involved in it, and therefore the effort was not so much to write a paper that would be satisfactory or create an impression this evening, but something that would bear looking into. The fact is, gentlemen, the conditions enumerated in that paper lie before us and they must be dealt with, and if any of you feel like backing up the engineer or the conditions that exist, the best thing to do is to take that paper and see whether you can remedy it, or whether you will put up with the trouble cheerfully.

The President: I think it is entirely unnecessary that the author of the paper should offer any apology. Personally I feel, and I am sure the rest of the members feel that it is a paper we shall feel proud of having presented to us.

It has been regularly moved and seconded that a vote of thanks be extended to the author of this very excellent paper. All in favor signify by saying "Aye." Contrary "No." It is unanimous.

Adjourned.

APPENDIX

After the paper was read certain curves and charts were thrown upon a screen by means of a stereopticon, and their characteristics explained and the effects of these in train control discussed. Obviously, such explanation, even though reproduced verbatim would be unintelligible as a pointer was employed to designate this or that line or figure, which cannot be reproduced in print. It has, therefore, been thought best to give a brief explanation of the charts instead of trying to reproduce the stereopticon lecture, cross references being given in the text of the paper to this explanation and from this back to the subject matter these are intended to supplement and emphasize.

Until very recently air brake questions have been settled strictly according to individual opinion—there being no standard of reference except the individual who was supposed to be an authority in air brake matters. Now these questions are settled by a reference to a standard written by the apparatus itself; viz. the indicator card registering what actually takes place during the action in question. Consequently, we have but one answer and that the correct one. To a question involving like conditions, it is no uncommon thing to get several different answers from the different authorities. Any one of them may be right and all of them may be wrong, for each authority is probably assuming different conditions, as but few questions are asked which are complete, or if the question is complete, it is so general in character that a large volume would be required to completely answer it. For instance, What will cause a slid flat wheel?

Fig. 1 illustrates graphically, when compared with Figures 5 and 6, how length of train affects the application of the brake both as regards pressure and time. It will be seen that with the old type of triple valve very little cylinder pressure was obtained on any of the cars and that there was an interval of 45 seconds between the application of the first and last brakes in the train. The curves for the "K" valve show that not only can the difference in time of application be overcome in a large degree, as here the interval between the first and last brakes was but 10 seconds, but also that a more effective cylinder pressure was obtained.

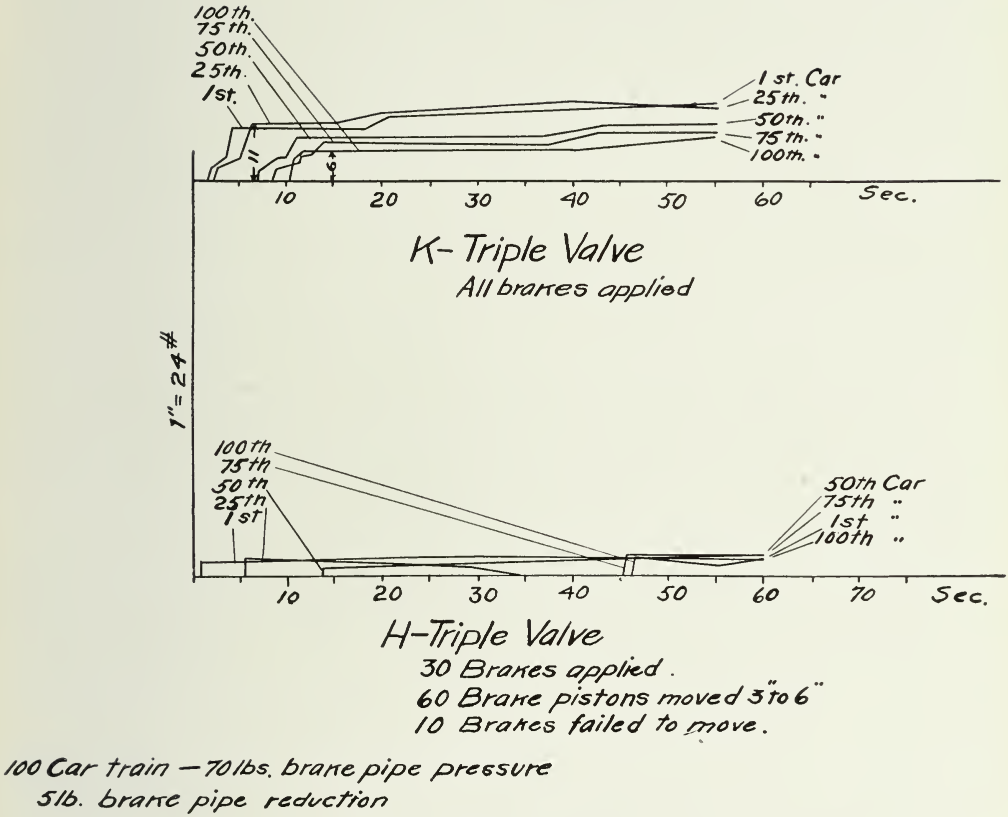

100th.
75th.
50th.
25th.
1st.
1st. Car
25th. "
50th. "
75th. "
100th. "
10 20 30 40 50 60 Sec.
K-Triple Valve
All brakes applied
1" = 24#
100th
75th
50th
25th
1st
50th Car
75th "
1st "
100th "
10 20 30 40 50 60 70 Sec.
H-Triple Valve
30 Brakes applied.
60 Brake pistons moved 3" to 6"
10 Brakes failed to move.
100 Car train — 70 lbs. brake pipe pressure
5 lb. brake pipe reduction

Fig. 1.

Fig. 2 differs from Fig. 1 in that a 10 pound reduction instead of a 5 pound was made, and a comparison between the two sets of cylinder cards shows how much more effective and uniform in operation the brake is when the time element in the application is reduced to a minimum.

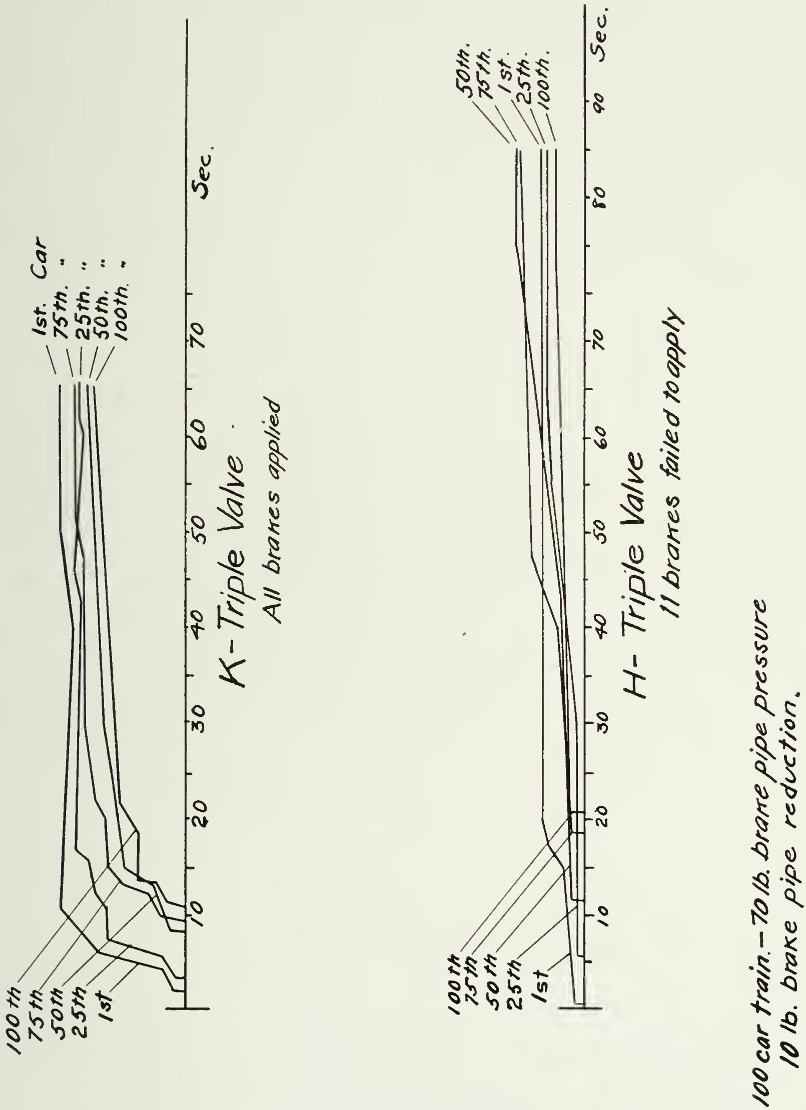

K-Triple Valve
All brakes applied
H- Triple Valve
11 brakes failed to apply
100 car train.—70 lb. brake pipe pressure
10 lb. brake pipe reduction.

FIG. 2.

Fig. 3 differs from Fig. 2 in that the reduction was 15 pounds instead of 10 pounds.

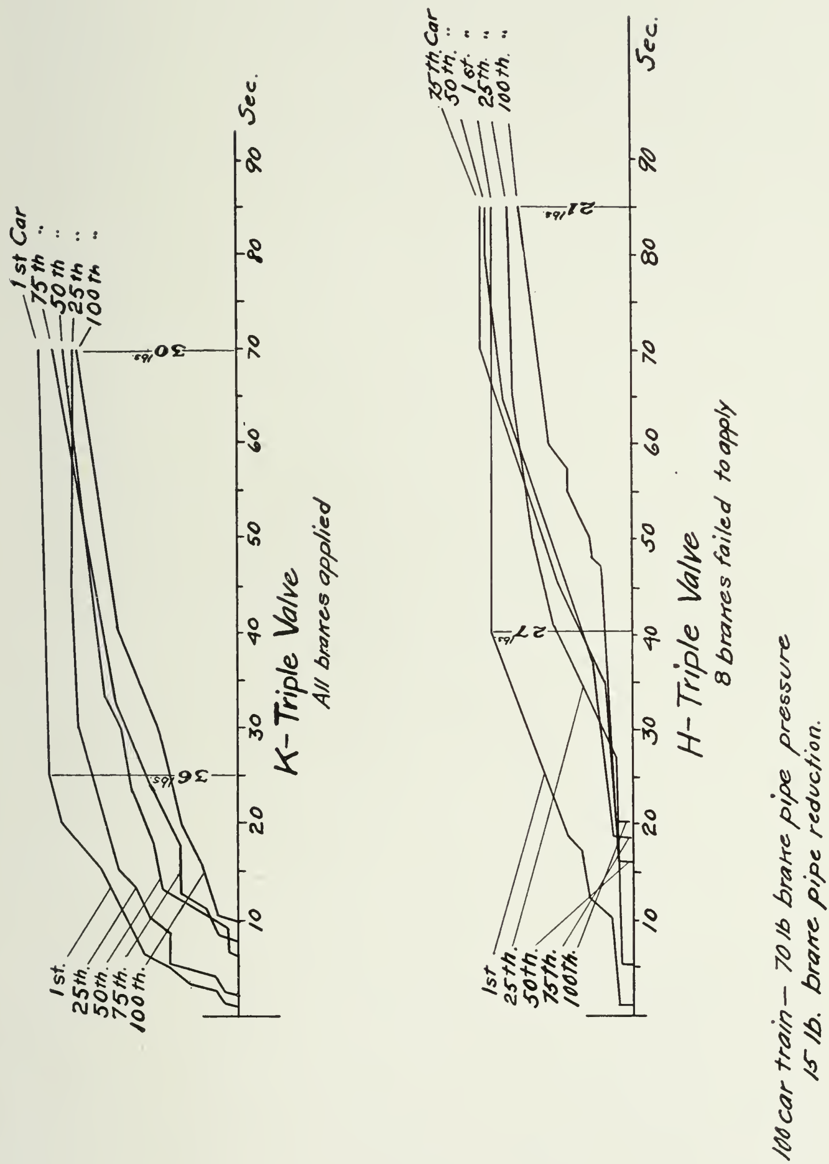

1st Car
75th
50th
25th
100th
30 lbs.
36 lbs.
1st.
25th.
50th.
75th.
100th.
10 20 30 40 50 60 70 80 90 Sec.
K-Triple Valve
All brakes applied
75th Car
50th
1st.
25th.
100th.
21 lbs.
27 lbs.
1st
25th.
50th.
75th.
100th.
10 20 30 40 50 60 70 80 90 Sec.
H-Triple Valve
8 brakes failed to apply
100 car train — 70 lb brake pipe pressure
15 lb. brake pipe reduction.

FIG. 3.

Fig. 4 differs from Fig. 3 in that the reduction was 20 pounds by a full service application instead of 15 pounds. A glance at this set of charts will show that they are self-explanatory. As to operation effects—the difference in time and pressure can only be appreciated by those who have had experience in brake matters, or who are willing to be governed by those who have.

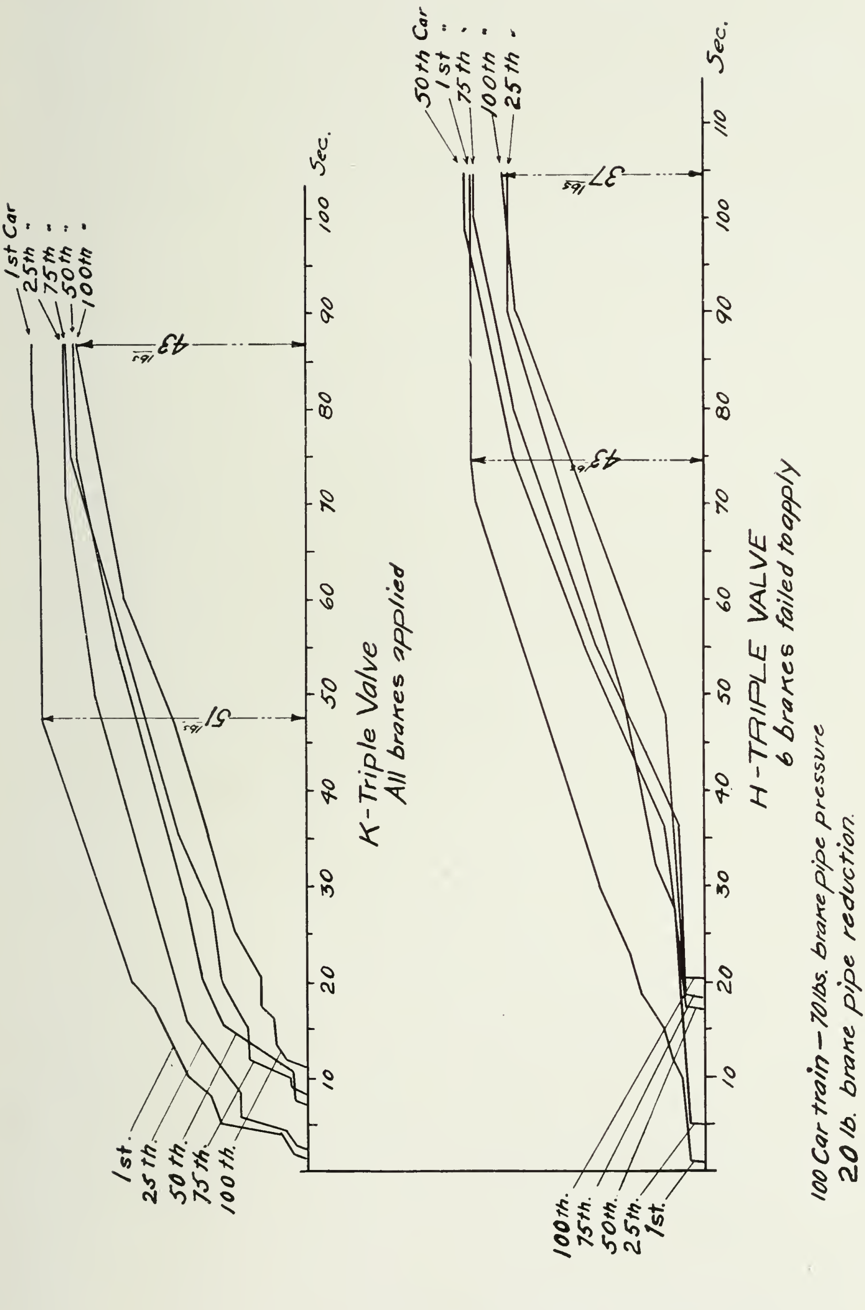

K-Triple Valve
All brakes applied
1st Car
25th "
75th "
50th "
100th "
43 lbs.
51 lbs.
1st.
25 th.
50 th.
75 th.
100 th.
H-TRIPLE VALVE
6 brakes failed to apply
50th Car
1st "
75th "
100th "
25th "
37 lbs.
43 lbs.
100th.
75th.
50th.
25th.
1st.
Sec.
10
20
30
40
50
60
70
80
90
100
110
100 Car train — 70 lbs. brake pipe pressure
20 lb. brake pipe reduction.

FIG. 4.

Fig. 5. The cylinder cards of this figure, when compared with Figs. 1 to 4 inclusive, illustrate what a great difference in time and pressure exists between a long and short train, as here the interval of time between the application of the first and last brakes was but 6 seconds as compared with 45 seconds with a 100-car train and same type of triple valve; while with a 20-pound reduction maximum cylinder pressure was obtained in about 35 seconds instead of 105 seconds with a 100-car train.

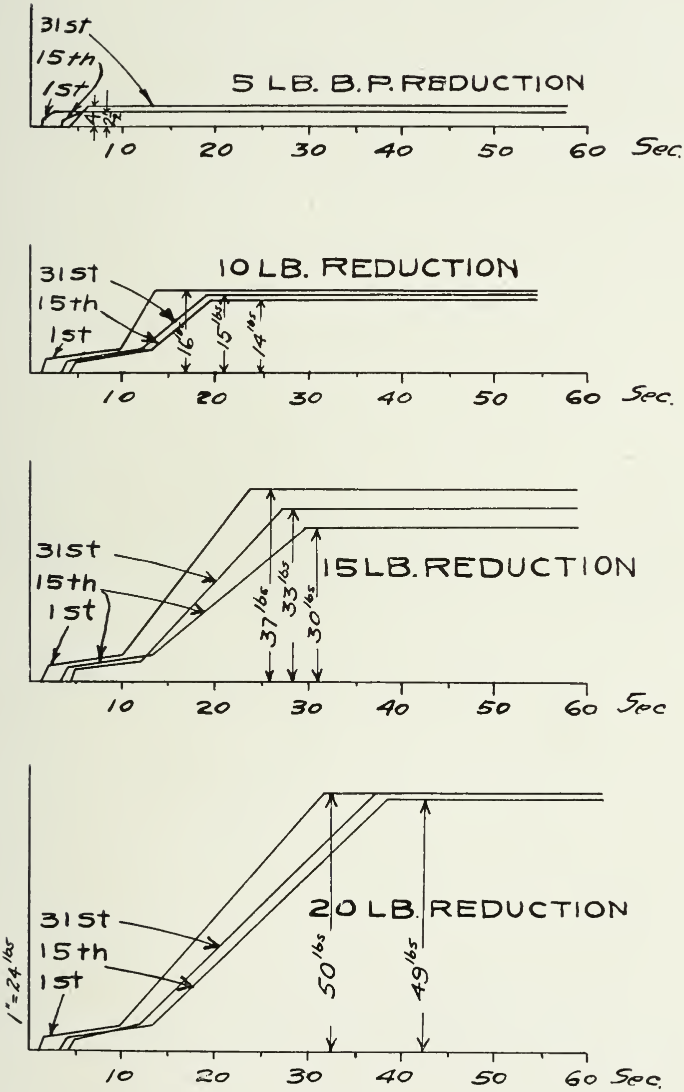
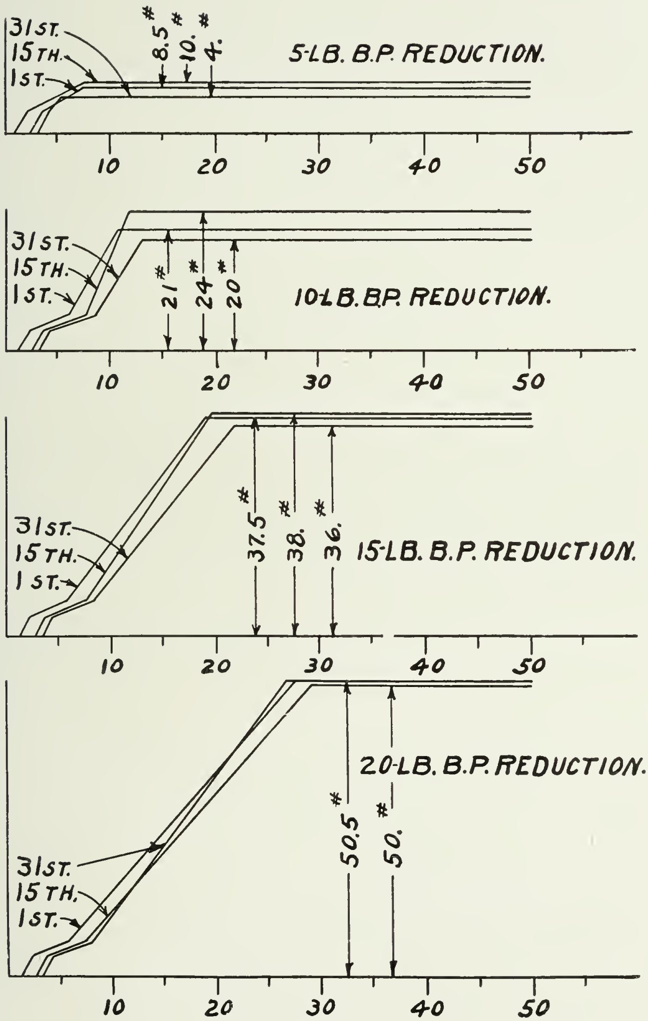

31st
15th
1st
5 LB. B.P. REDUCTION
10 20 30 40 50 60 Sec.
10 LB. REDUCTION
16 lbs
15 lbs
14 lbs
15 LB. REDUCTION
37 lbs
33 lbs
30 lbs
20 LB. REDUCTION
50 lbs
49 lbs
1" = 24 lbs

Fig. 5.

Fig. 6 is similar to Fig. 5, except that the cards were made from the quick service triple valves. These curves show that the effect of brake pipe volume, due to length of train at the time of application, is less than with the old type of valve.



31ST.
15TH.
1ST.
8.5#
10.#
4.#
5-LB. B.P. REDUCTION.
21#
24#
20#
10-LB. B.P. REDUCTION.
37.5#
38.#
36.#
15-LB. B.P. REDUCTION.
50.5#
50.#
20-LB. B.P. REDUCTION.
10
20
30
40
50

FIG. 6.

Fig. 7 illustrates the difference in time and pressure in the application of the brakes on the 1st, 25th and 50th cars. Not only is the rise of cylinder pressure shown, but also the rate of fall in brake pipe pressure, which will seem to be very slow on a train of even this length.

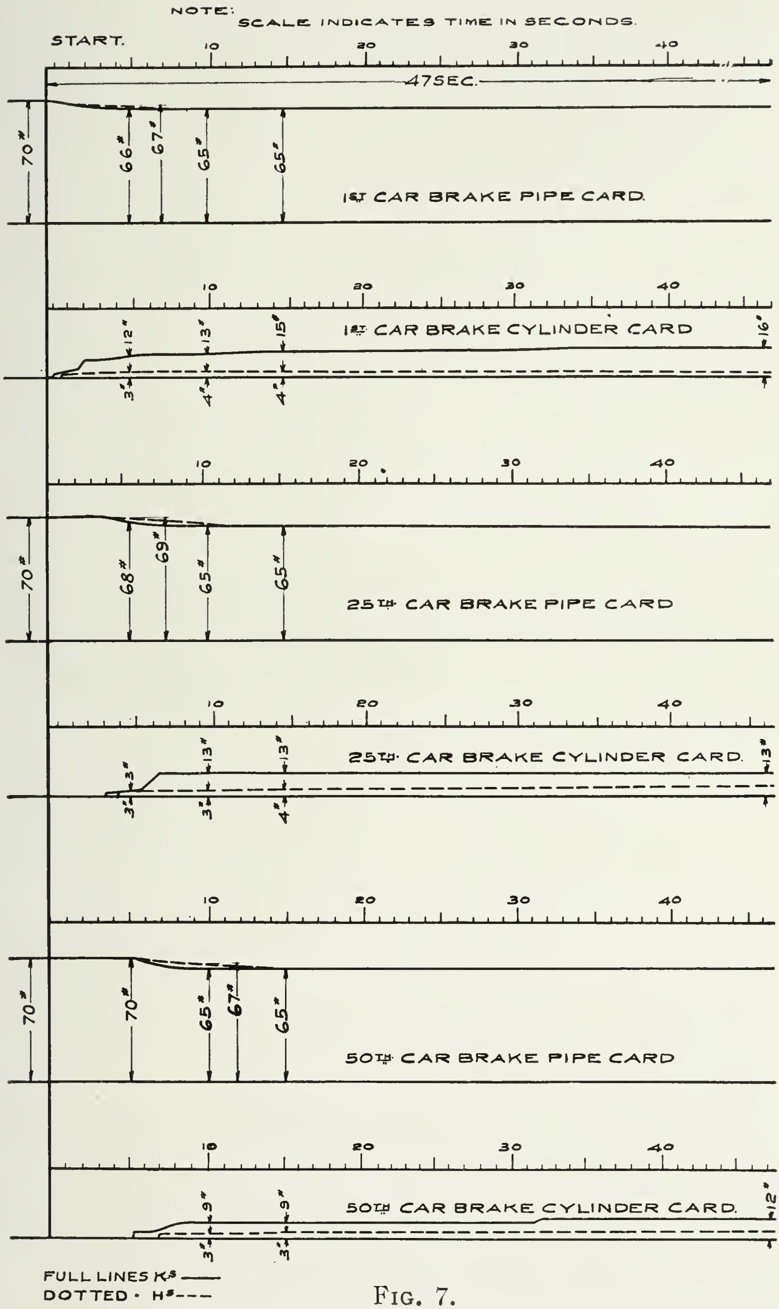

NOTE:
SCALE INDICATES TIME IN SECONDS.
START.
47 SEC.
1ST CAR BRAKE PIPE CARD.
1ST CAR BRAKE CYLINDER CARD
25TH CAR BRAKE PIPE CARD
25TH CAR BRAKE CYLINDER CARD.
50TH CAR BRAKE PIPE CARD
50TH CAR BRAKE CYLINDER CARD.
FULL LINES K's ——
DOTTED · H's ---

FIG. 7.

Fig. 8 is similar to Fig. 7, except that a 10 pound reduction was made and consequently the differences in the results are more pronounced, both as between the brakes on the different cars and between the two types of valves with which the two trains were equipped.

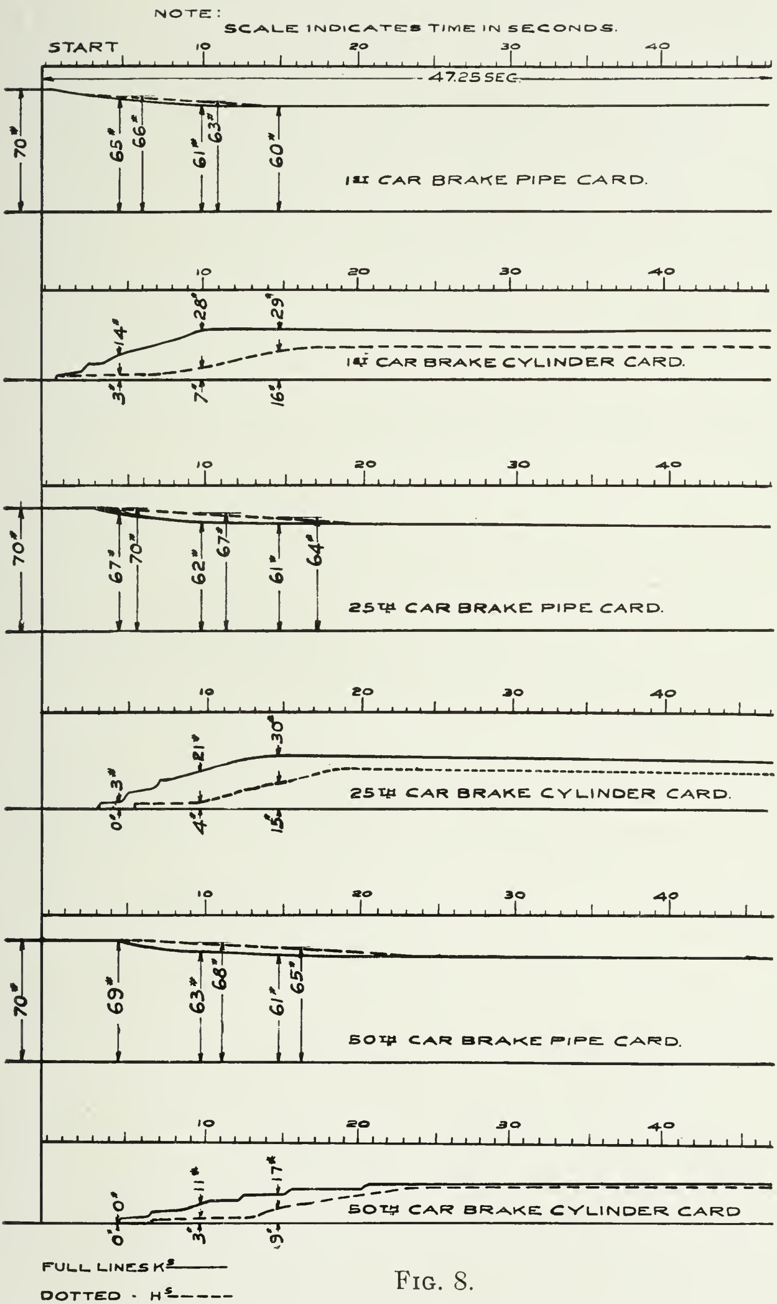

NOTE:
SCALE INDICATES TIME IN SECONDS.
START
47.25 SEC.
1ST CAR BRAKE PIPE CARD.
1ST CAR BRAKE CYLINDER CARD.
25TH CAR BRAKE PIPE CARD.
25TH CAR BRAKE CYLINDER CARD.
50TH CAR BRAKE PIPE CARD.
50TH CAR BRAKE CYLINDER CARD
FULL LINES K^s ———
DOTTED · H^s - - - - -

Fig. 8.

Fig. 9 is similar to Fig. 8—the difference resulting from a 15 pound reduction having been made instead of 10 pounds.

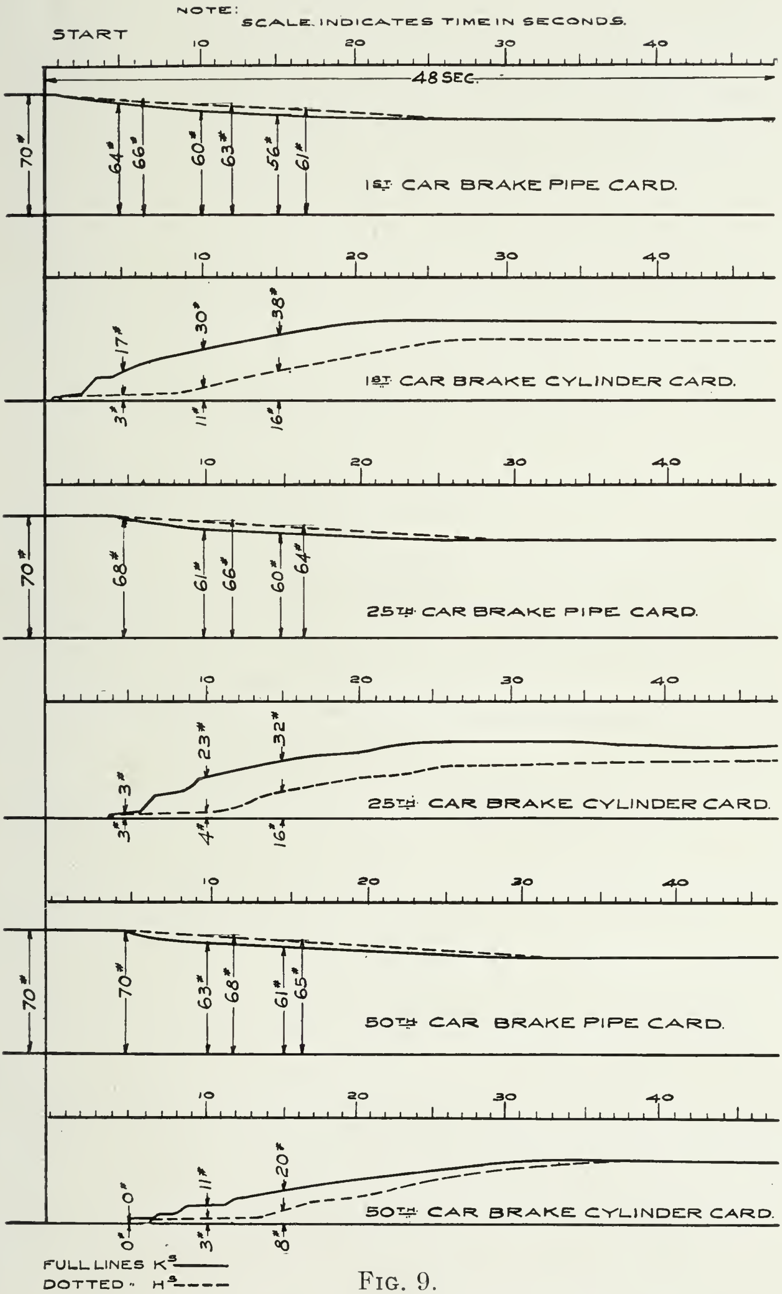

NOTE:
SCALE INDICATES TIME IN SECONDS.
START
48 SEC.
1ST. CAR BRAKE PIPE CARD.
1ST. CAR BRAKE CYLINDER CARD.
25TH. CAR BRAKE PIPE CARD.
25TH. CAR BRAKE CYLINDER CARD.
50TH. CAR BRAKE PIPE CARD.
50TH. CAR BRAKE CYLINDER CARD.
FULL LINES K^S
DOTTED " H^S

FIG. 9.

Fig. 10 differs from the preceding figure because of a 20 pound reduction having been made instead of 15 pounds. This series makes quite clear how much more effective and controllable a brake becomes when the time required to obtain certain brake effectiveness from one end of the train to the other is reduced.

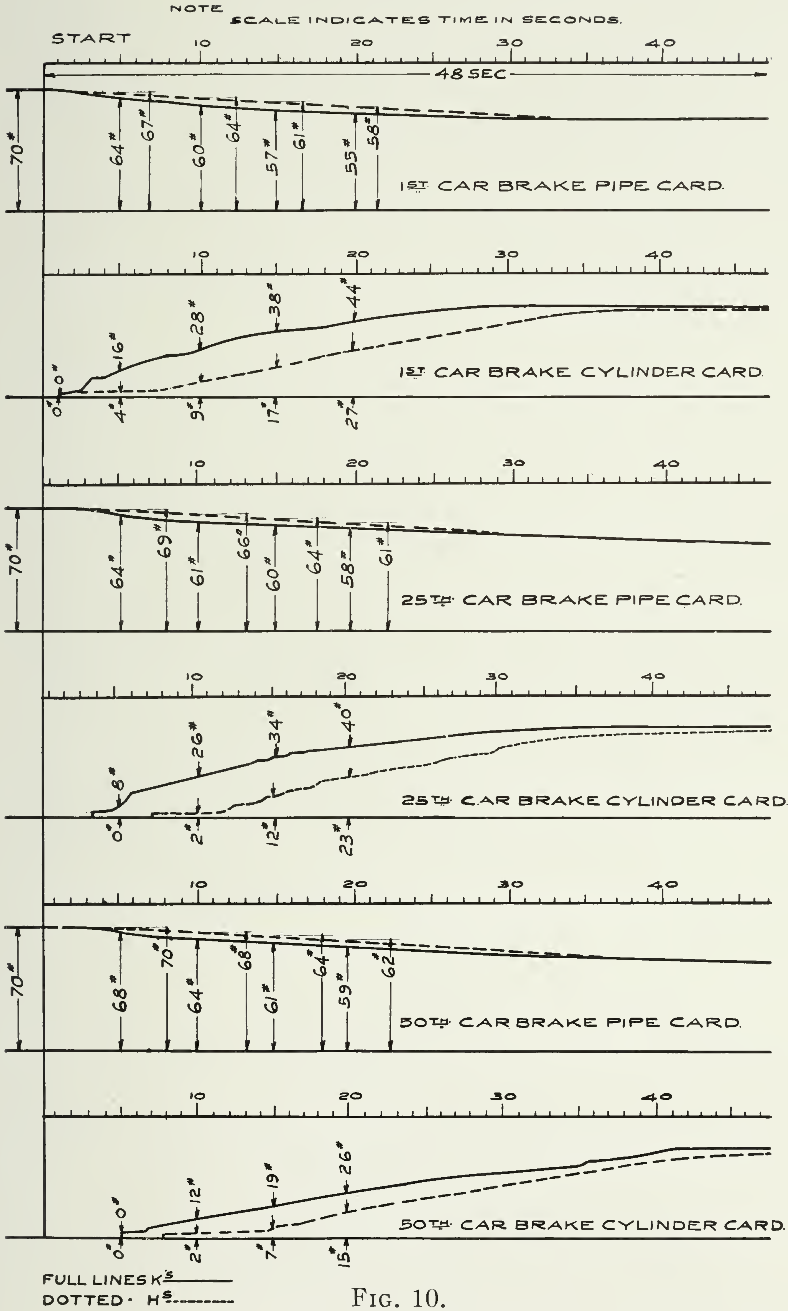
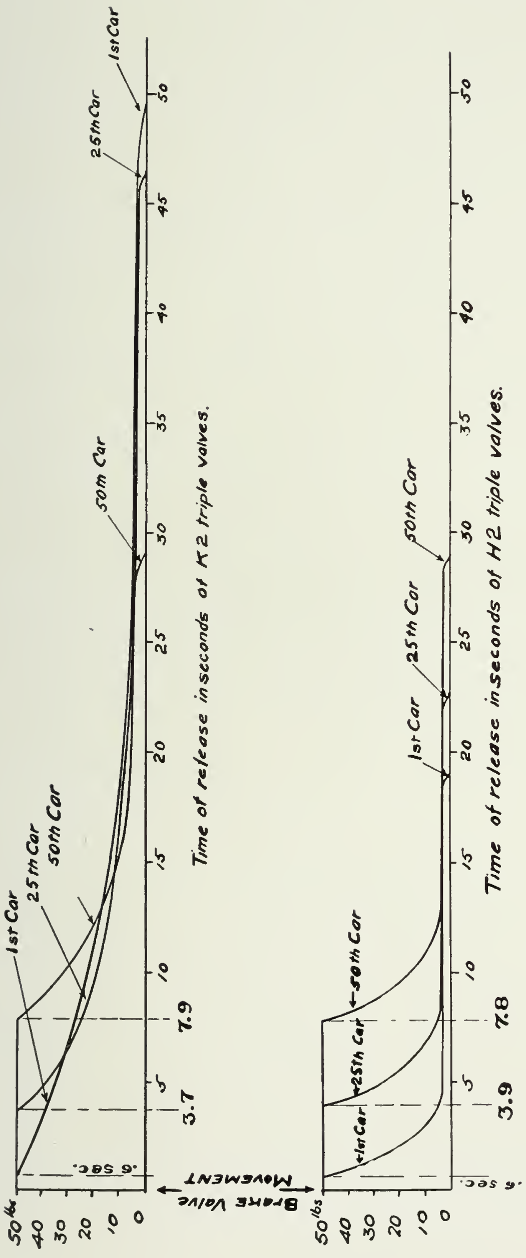

NOTE
SCALE INDICATES TIME IN SECONDS.
START
48 SEC
70#
1ST CAR BRAKE PIPE CARD.
1ST CAR BRAKE CYLINDER CARD.
25TH CAR BRAKE PIPE CARD.
25TH CAR BRAKE CYLINDER CARD.
50TH CAR BRAKE PIPE CARD.
50TH CAR BRAKE CYLINDER CARD.
FULL LINES K'S
DOTTED · H'S

FIG. 10.

Fig. 11 illustrates graphically both differences in time of release between the 1st, 25th and 50th cars of a train and the action of the brakes in the release when the retarded release type of triple valves is employed. It will be seen from the lower of the two sets of cylinder cards that the first brake was released in .6 of a second and was entirely off when the 25th brake commenced to release, which was about $3\frac{1}{2}$ seconds later and that the 25th brake was off before the 50th commenced to release, which was about 4 seconds behind the 25th. It will thus be seen that there is an interval of about 9 seconds between the release of the 1st brake and the 50th and that the difference in the release of brakes between the 25th and 50th is 4 seconds—time enough for the retardation still going on at the rear to do considerable damage if the slack runs out.

From the upper set of cylinder cards, it will be seen that while the brakes commence to release with about the same difference in time that the release as a whole is very much more uniform—the effect being to eliminate surges in the train, due to brake release; thus doing away with a prolific source of damage and break-in-two.



Cylinder Cards Showing Release of K2 + H2 (H49) Triple Valves.
50 Car Train. — Brake Pipe Pressure 70 Lbs.
Main Reservoir Capacity 50000 Cu. In. — Main Reservoir Pressure 110 Lbs.

FIG. 11.

Fig. 12 illustrates the difference in time of release between the 1st, 25th and 50th cars of a train, both as regards the different cars and two different types of valves. This and the cards shown on the following three figures are instructive also as illustrating the rate of rise of brake pipe pressure of a train of this length, namely, 50 cars.

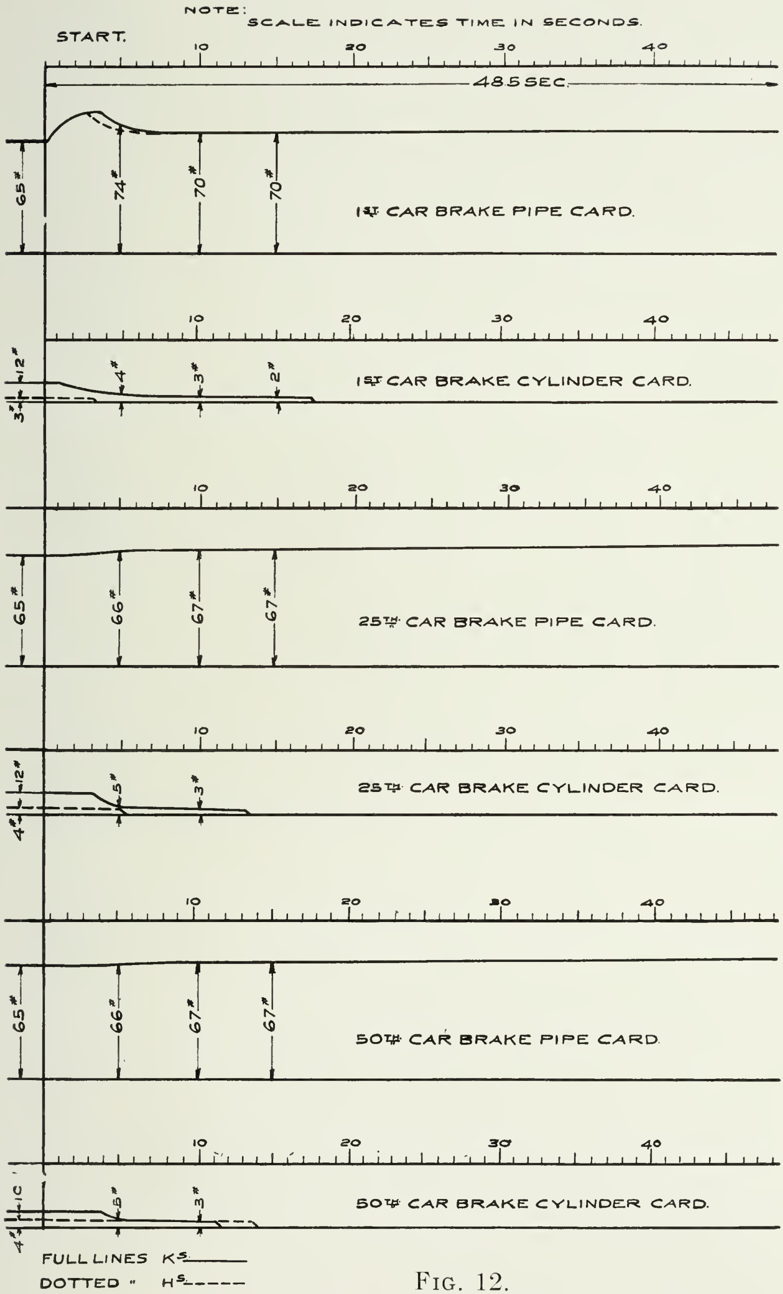

NOTE:
SCALE INDICATES TIME IN SECONDS.
START.
48.5 SEC.
1ST CAR BRAKE PIPE CARD.
1ST CAR BRAKE CYLINDER CARD.
25TH CAR BRAKE PIPE CARD.
25TH CAR BRAKE CYLINDER CARD.
50TH CAR BRAKE PIPE CARD.
50TH CAR BRAKE CYLINDER CARD.
FULL LINES K'S
DOTTED " H'S

FIG. 12.

Fig. 13 differs from Fig. 12 in that it is a release after a 10-pound reduction instead of a 5-pound.

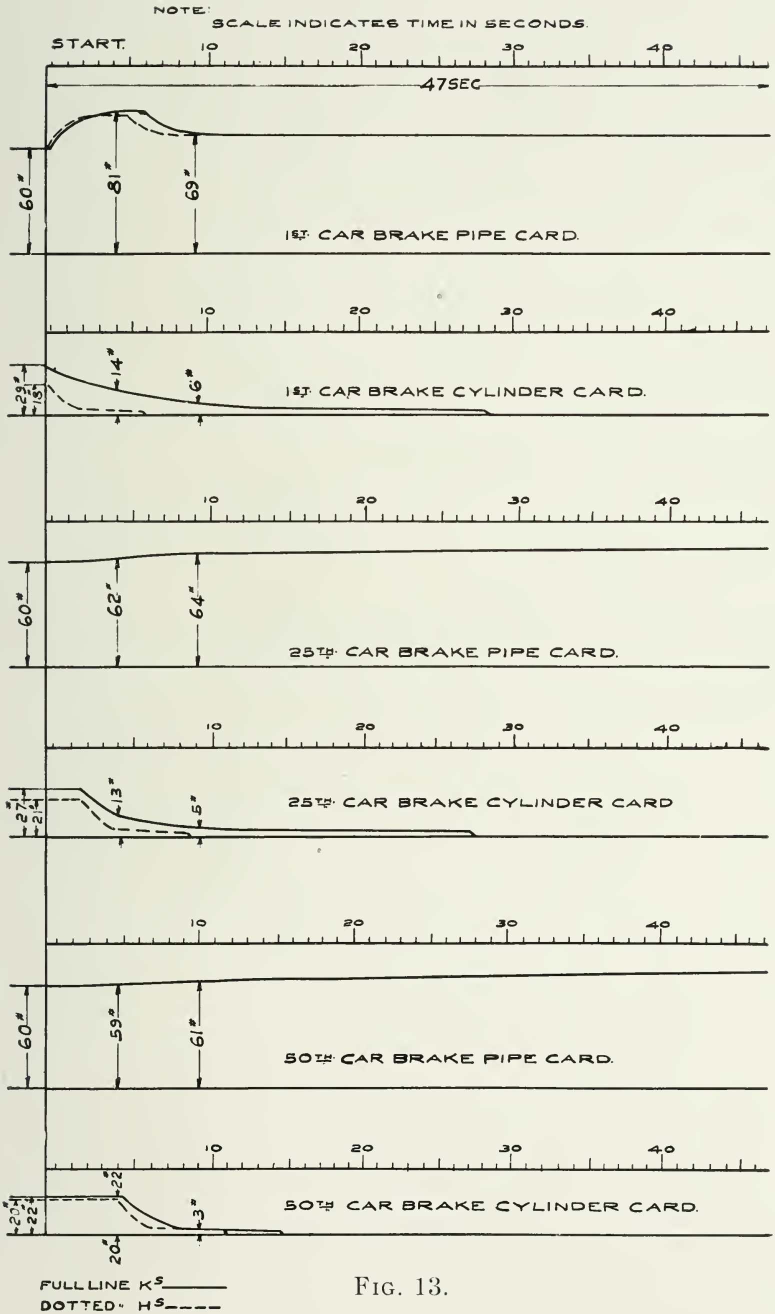

NOTE:
SCALE INDICATES TIME IN SECONDS.
START.
10
20
30
40
47 SEC
60#
81#
69#
1ST. CAR BRAKE PIPE CARD.
14#
6#
29#
21#
13#
1ST. CAR BRAKE CYLINDER CARD.
62#
64#
25TH. CAR BRAKE PIPE CARD.
13#
5#
27#
21#
25TH. CAR BRAKE CYLINDER CARD
59#
61#
50TH. CAR BRAKE PIPE CARD.
22#
3#
20#
50TH. CAR BRAKE CYLINDER CARD.
FULL LINE K^S
DOTTED " H^S

FIG. 13.

Fig. 14 illustrates the difference in time of commencement of release of the brake and fall of cylinder pressure on the cars after a 15-pound reduction.

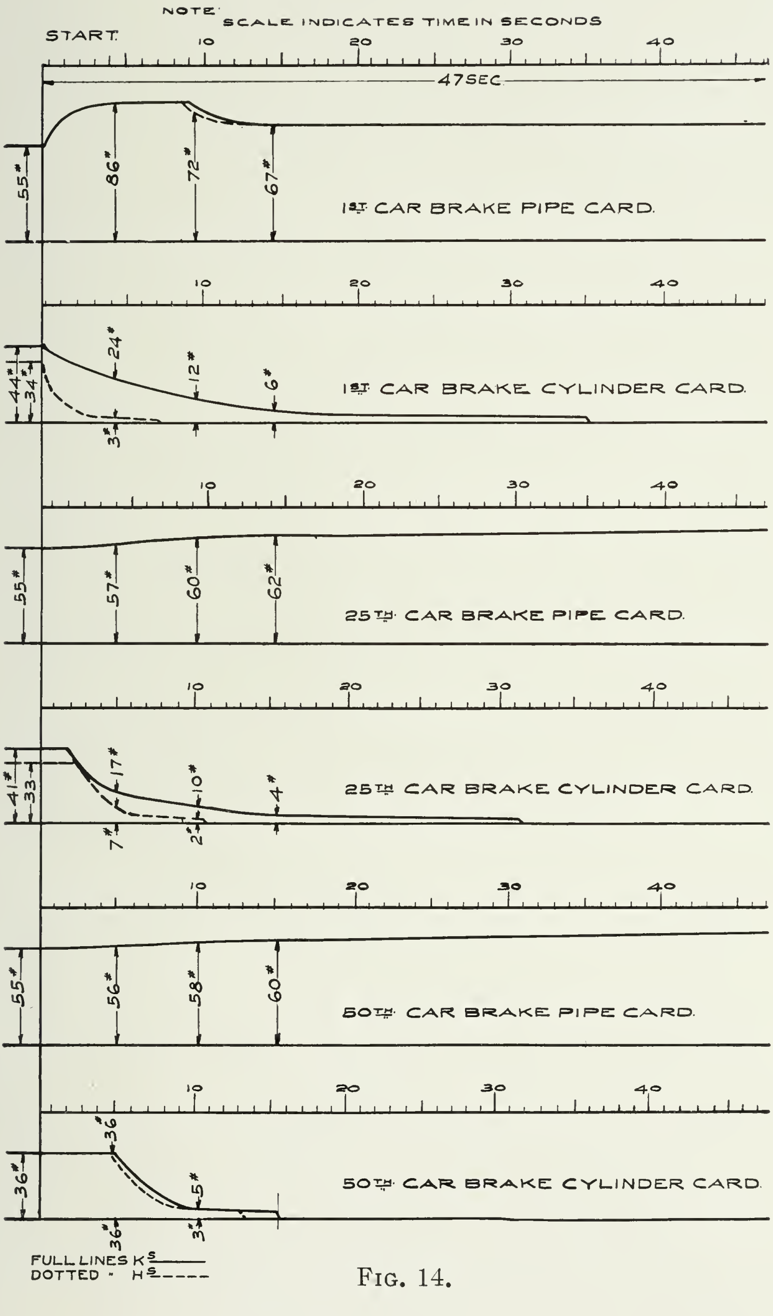

NOTE:
SCALE INDICATES TIME IN SECONDS
START.
47 SEC.
1ST. CAR BRAKE PIPE CARD.
1ST. CAR BRAKE CYLINDER CARD.
25TH. CAR BRAKE PIPE CARD.
25TH. CAR BRAKE CYLINDER CARD.
50TH. CAR BRAKE PIPE CARD.
50TH. CAR BRAKE CYLINDER CARD.
FULL LINES KS
DOTTED " HS

FIG. 14.

Fig. 15. The cards of this figure are taken from a 20 pound reduction and illustrate the rate of rise of brake pipe pressure between the different cars of the train, the amount of cylinder pressure obtained, the time of release between the different cars, and the difference in the rate of release of cylinder pressure between the different cars of the train and between the different types of valves. For example, with the old type of valve, the pressure was all out of the cylinder of the first car 3 seconds before the brake of the last car commenced to release; while with the new type of valve, there was 25 pounds in the cylinder of the first car when the brake of the last or 50th car commenced to release and about 10 pounds in the cylinder of the first car when the effective pressure was out of the cylinder of the last car. In other words, the brake of the last car was released before that of the first car; thus the difference in time due to length of train was practically eliminated. The great value of this can only be appreciated by those who know the effects of having the rear end of the train anchored while the front end is running free.

Whatever difference in cylinder pressure there appears on the different sets of charts above mentioned has been due to the influence of the time factor as the piston travel was uniform. In the figures that follow the difference in cylinder pressure that appears is due to variation of piston travel, that is, increase or decrease of brake piston movement, which by the grace of somebody may exist before the shoes bear on the wheels.

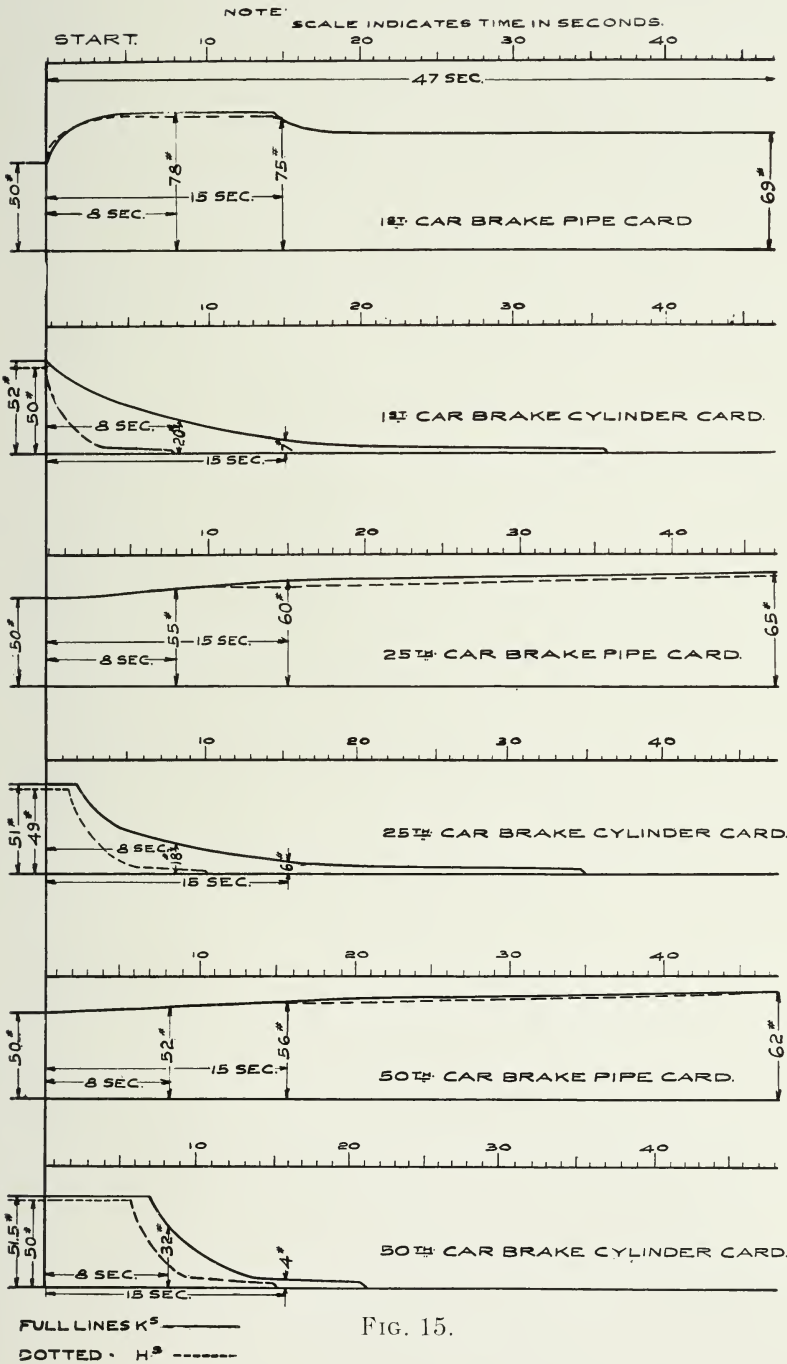
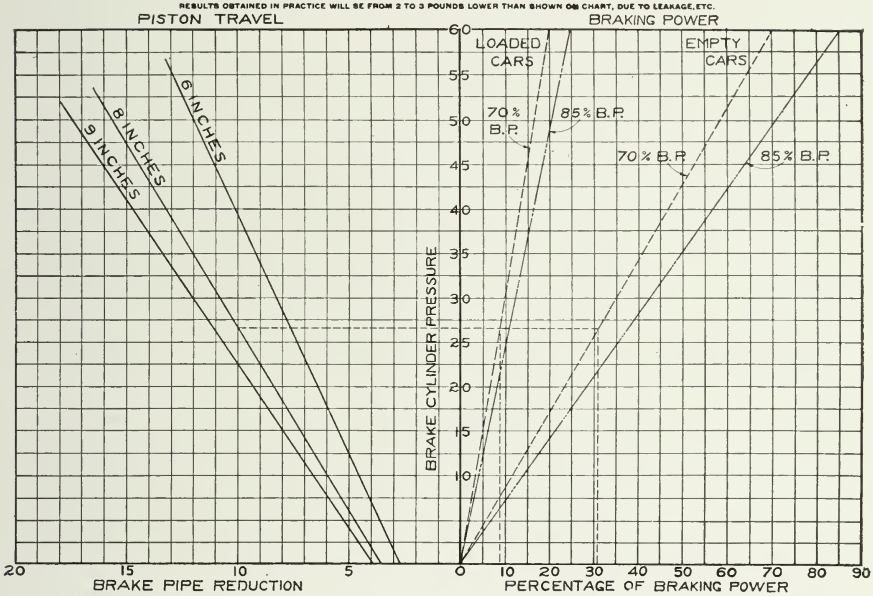

NOTE: SCALE INDICATES TIME IN SECONDS.
START.
47 SEC.
1ST CAR BRAKE PIPE CARD
1ST CAR BRAKE CYLINDER CARD.
25TH CAR BRAKE PIPE CARD.
25TH CAR BRAKE CYLINDER CARD.
50TH CAR BRAKE PIPE CARD.
50TH CAR BRAKE CYLINDER CARD.
8 SEC.
15 SEC.
FULL LINES K^S
DOTTED · H^S

FIG. 15.

Fig. 16. The significance of the curves of this chart is pointed out on page 19 of this reprint of the paper. A prolonged study of this chart will cause considerable reflection, if nothing more concrete, and perhaps some may even ask these questions—how did we ever permit such conditions to come into existence, and why do we permit them to continue?

CHART SHOWING THE DIFFERENCE IN BRAKING POWER ON LOADED AND EMPTY CARS WITH ANY GIVEN BRAKE PIPE REDUCTION, VARYING PISTON TRAVEL AND BOTH 70 AND 85 PER CENT BRAKING POWER BASED ON 60 LBS. CYLINDER PRESSURE.

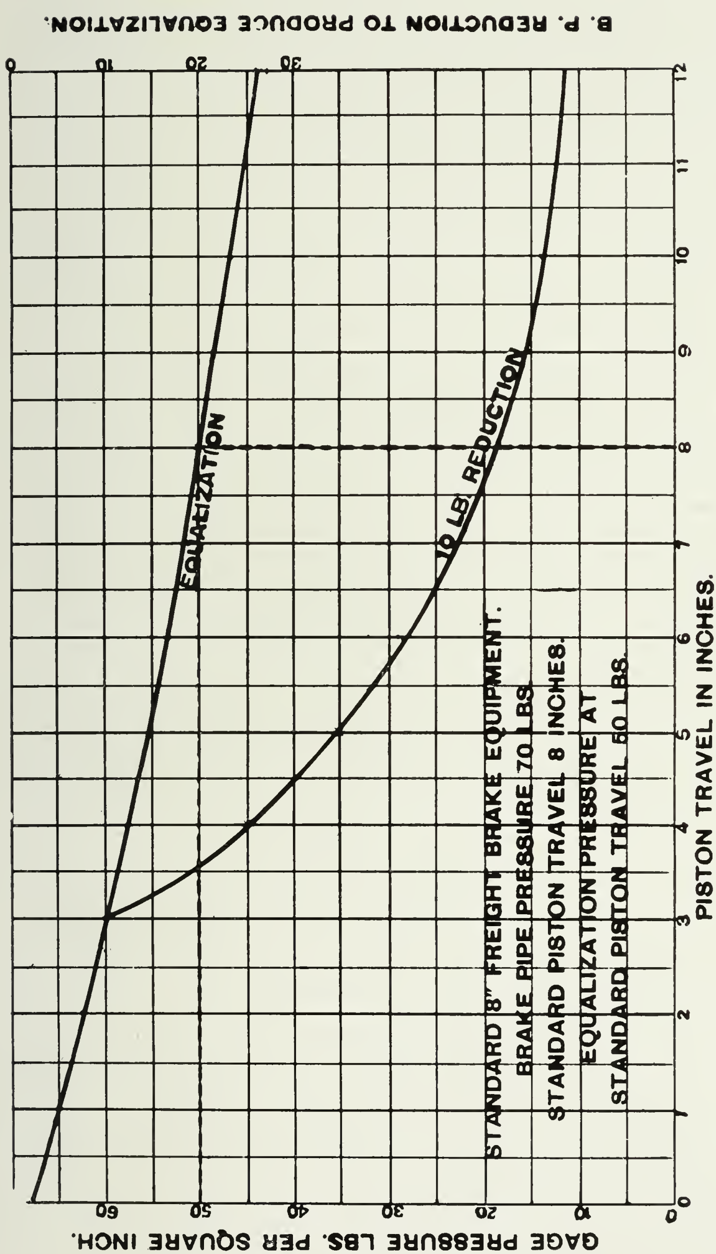
RESULTS OBTAINED IN PRACTICE WILL BE FROM 2 TO 3 POUNDS LOWER THAN SHOWN ON CHART, DUE TO LEAKAGE, ETC.



SERVICE EQUALIZATION 53.6 POUNDS

FIG. 16.

Fig. 17. This chart is very instructive as illustrating how the braking power may vary, due to no other cause than lack of piston travel maintenance. As the chart is largely self-explanatory, it will be sufficient to point out that the air stored in the auxiliary reservoir at 70 pounds may equalize into the brake cylinder at any pressure from 67 pounds down to 44 pounds contingent only upon difference in piston travel. But as the damage is done long before equalization of pressure is reached, we would show what results from a 10-pound reduction, which is the critical one of an application. Here we see the pressure obtained from a 10-pound reduction may vary from 60 pounds with 3″ piston travel to only 12 pounds with 12″ piston travel, and what is worse in its effect in producing shocks that 60 pounds is obtained in the same time as the 12 pounds. Of course, there may be any of the variations between these two extremes. Now what does the engineer have to do with this, or how is he to prevent the results? Every car man and inspector should be drilled until he knows by heart what produces these curves and what their effects may be.



EFFECT OF PISTON TRAVEL ON BRAKE.
CYLINDER PRESSURE OBTAINED FOR 10 LB.
REDUCTION AND ON EQUALIZATION.

Fig. 17.

Fig. 18. This chart carries the investigation of the effect of varying piston travel further, in that we are able to see what it means in the braking power on the car and from this infer what such un-uniformity may mean to the train as a whole, particularly if we figure the various combinations and distribution that may occur. It will be seen that with the braking power designed for 70% of the light weight of the car a 10-pound reduction will result in about 9 pounds cylinder pressure and about 10% braking power on the car with long piston travel; while on the car with short piston travel for the same direction and in the same time the cylinder pressure will be 32 pounds and the braking power 35%. A further investigation of the curves will disclose a multitude of possible variations which, fortunately, may be held down to very narrow extremes by very little care, which, however, must be given before the train leaves the terminal, as the engineer is not furnished with any mechanism that will compensate for improper conditions of brake equipment, nor can he expect except in rare instances to avoid the consequences

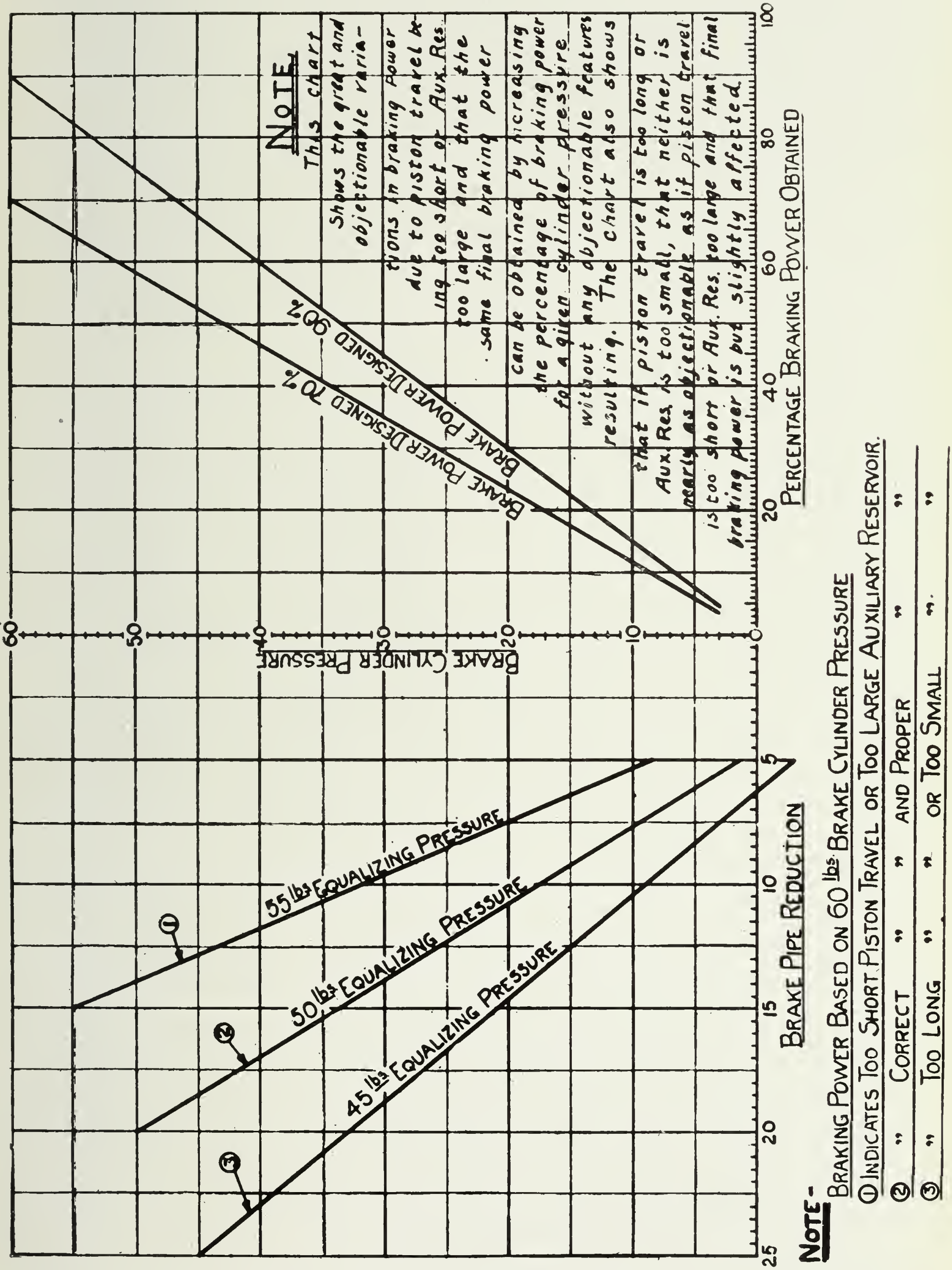

NOTE
This chart shows the great and objectionable variations in braking power due to piston travel being too short or Aux. Res. too large and that the same final braking power can be obtained by increasing the percentage of braking power for a given cylinder pressure without any objectionable features resulting. The chart also shows that if piston travel is too long or Aux. Res. is too small, that neither is nearly as objectionable as if piston travel is too short or Aux. Res. too large and that final braking power is but slightly affected.
BRAKE POWER DESIGNED 90%
BRAKE POWER DESIGNED 70%
BRAKE CYLINDER PRESSURE
0 10 20 30 40 50 60
PERCENTAGE BRAKING POWER OBTAINED
20 40 60 80 100
BRAKE PIPE REDUCTION
5 10 15 20 25
55 lbs EQUALIZING PRESSURE
50 lbs EQUALIZING PRESSURE
45 lbs EQUALIZING PRESSURE
NOTE -
BRAKING POWER BASED ON 60 lbs BRAKE CYLINDER PRESSURE
① INDICATES TOO SHORT PISTON TRAVEL OR TOO LARGE AUXILIARY RESERVOIR.
② " CORRECT " AND PROPER "
③ " TOO LONG " OR TOO SMALL "

FIG. 18.

Fig. 19 is a different method of illustrating this matter, but more graphically develops the comparatively slight differences in the equalized pressures and the great differences for partial applications for the same difference in piston travel. Also that the very high cylinder pressure resulting from short piston travel is obtained with less than half the reduction and in less than half the time that the equalized and lower pressure is obtained with the long travel. Plainly, few know that these things exist or few care—either horn of the dilemma is not comfortable and I may say neither is profitable. *Fortunately the most extreme neglect will not destroy the brake as an emergency safety device, but considerable care is required to retain its efficiency as a service brake, and this is all the more important as serious losses may otherwise result.* In other words, as with any thing less mechanical, certain physical conditions must exist if we are to obtain profitable and desired instead of unprofitable and undesired results. It would not be necessary to mention this if we were speaking of anything else but the air brake.

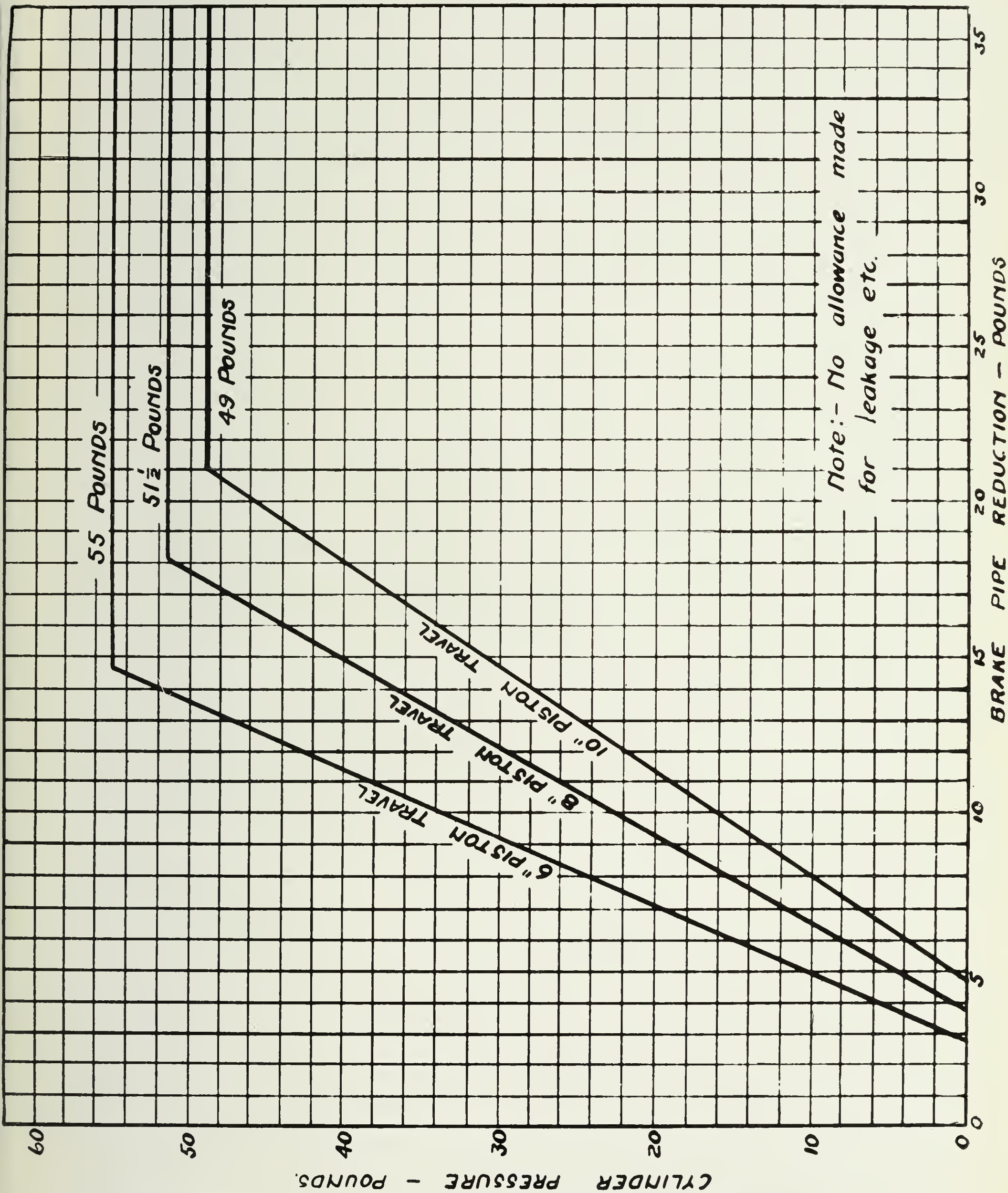

55 Pounds
51½ Pounds
49 Pounds
6" Piston Travel
8" Piston Travel
10" Piston Travel
Note:- No allowance made for leakage etc.
Brake Pipe Reduction — Pounds
0
5
10
15
20
25
30
35
Cylinder Pressure — Pounds.
0
10
20
30
40
50
60

Fig. 19.

Fig. 20 still further illustrates piston travel effects, it being hoped by the number and graphicness of the illustrations that some sort of notice will be taken of the importance of this element in its effect on train control. In this chart, the variation of both pressure and difference in percentage of braking power that may occur, either side of that desired in the design is shown.

Figs. 19 and 20 are analyzed on page 10 of the paper to some extent, to which the reader is referred. It is hoped that something has been said on this part of the subject which will impress upon all concerned the necessity of giving it the consideration that results in some action being taken.

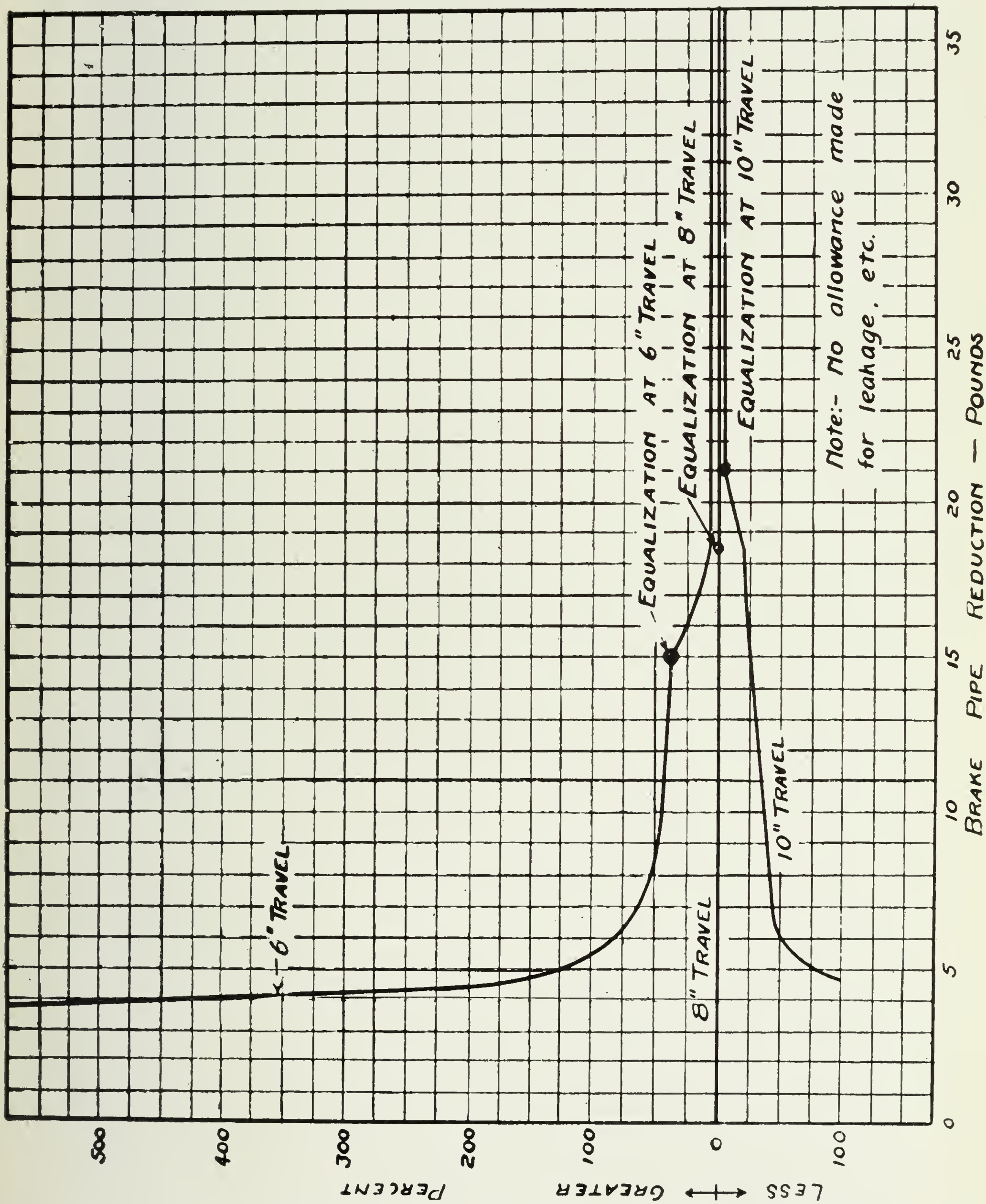

EQUALIZATION AT 6" TRAVEL
EQUALIZATION AT 8" TRAVEL
EQUALIZATION AT 10" TRAVEL
Note:- No allowance made for leakage, etc.
6" TRAVEL
8" TRAVEL
10" TRAVEL
0
5
10
15
20
25
30
35
BRAKE PIPE REDUCTION — POUNDS
500
400
300
200
100
0
100
PERCENT
GREATER ←→ LESS

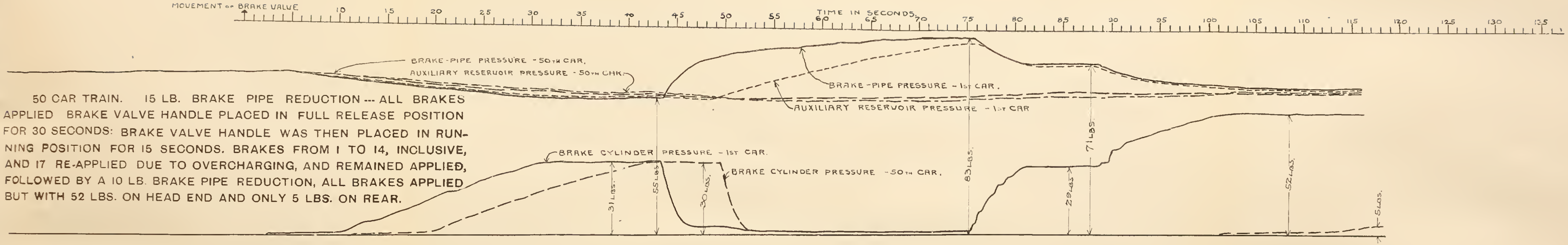
FIG. 20.

Fig. 21. This chart illustrates graphically the movement of the air and the action of the brakes both when the brake valve is manipulated, in releasing the brakes of a 75-car train, as it should be and as it should *not* be. Curve 1 proves how serious the improper manner of releasing the brakes may be—the result being "stuck brakes" and undesired quick action on the next application. The curves of this and the following figure are interesting and instructive in showing how the pressure rises and falls in different parts of the train and that the time interval between the action of the brake first and last is a factor to be reckoned with.

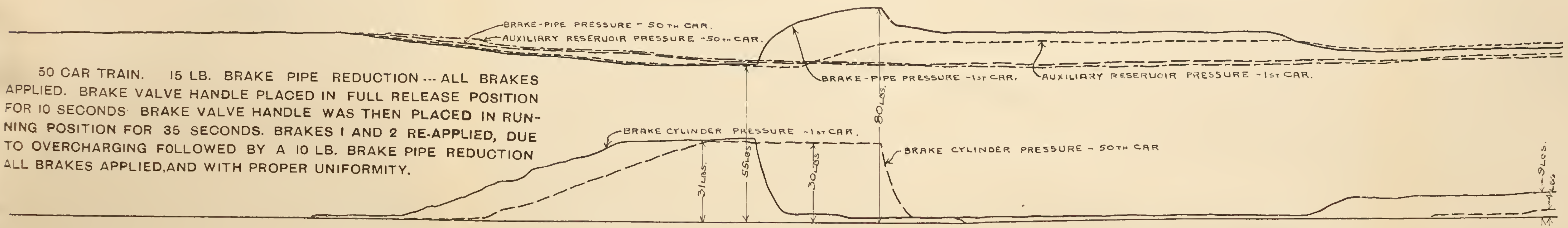
From a train operating standpoint, the curves shown on this chart are perhaps the most important ever recorded, for an inspection of those curves showing improper operation will demonstrate that a great many troubles and losses with the brake are due entirely to the improper use of the full release position. One reason for calling attention to these particularly is that all the evils resultant from such manipulation can be avoided without the expenditure of a dollar for apparatus or repairs. It will be seen from curves 1 and 3 that overcharging, stuck brakes, undesired quick action are the resultant of such improper methods of manipulation. It almost seems needless to say that in a train with this we have flat wheels, cracked wheels, broken wheels, buckling of trains, and break-in-twos, as well as a great number of happenings of lesser significance.

Another thing, however, should be pointed out, namely, that such methods in grade work result in the forward brakes of the train doing practically all the work of controlling the train, which viewed from any standpoint is bad.

Curves 2 and 4. (Fig. 21.) It will be seen that none of these things result when the proper method is employed. In fact, just the contrary for the operation of the brakes is then all that can be desired as far as brake valve control is concerned. A note on each curve briefly gives the operation and result, but an individual analysis of each of the curves cannot fail to convince all concerned that there are some things to avoid when operating the brakes.

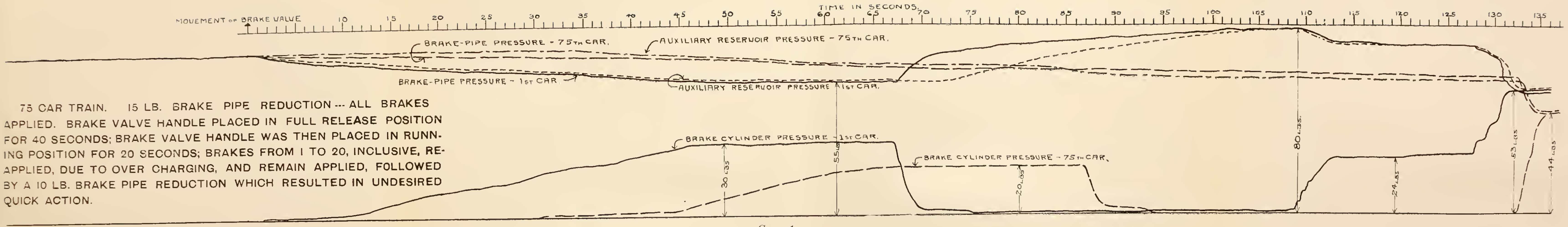


Curve 3.

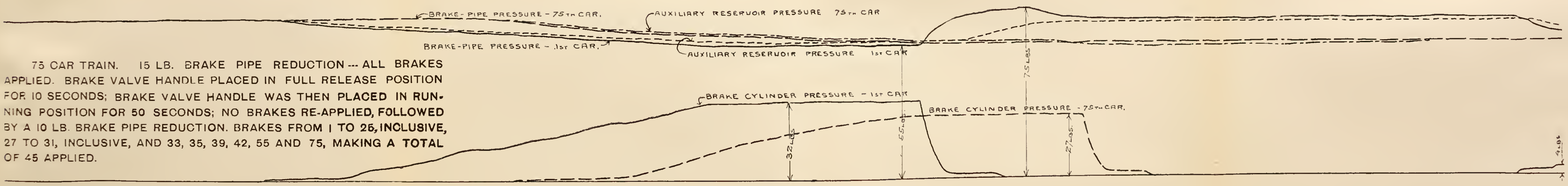


Curve 4.

FIG. 21.



Curve 1.



Curve 2.
FIG. 21.

Figs. 22 to 27, inclusive are intended to show the difference in time in the release of the brakes when using running position with a 30-car train and full release position with an 80-car train after both a 10 and 20-pound reduction. These curves also show that the rise of pressure is much more rapid with the brake valve in running position for a 30-car train than in full release position for an 80-car train. In fact, these charts were made to demonstrate, to some who doubted, that the brake which will release when full release position is used on an 80-car train is even more certain to release in a 30-car train if only running position is used.

Another point worthy of notice is that some of the brakes on the 80-car train had not released by the time the brake valve handle was returning to running position, consequently, they were released from running position. The vertical lines show when the triple valve went to release position, as at this point the indicator was closed and opened again quickly. Some of the lessons to be learned from these four charts are, if the brake valve handle is held in release position long enough to insure that all brakes are released while the handle is in this position, that the head end of the train will be overcharged, that the time of the release of the brake depends more upon the length of the train than the position of the brake valve handle and that the rise of brake pipe pressure when releasing the brakes, like the fall of pressure when applying the brakes, is also dependent more upon the length of the train than upon the position of the brake valve, and finally that the interval between the release of the first brake and the last is dependent upon the length of train. Of course, these differences both in application and release are very much reduced and greater uniformity secured by the later type of triple valve, but even with these, better results will be obtained if it is understood that different conditions involve different results unless the manipulation be modified accordingly.

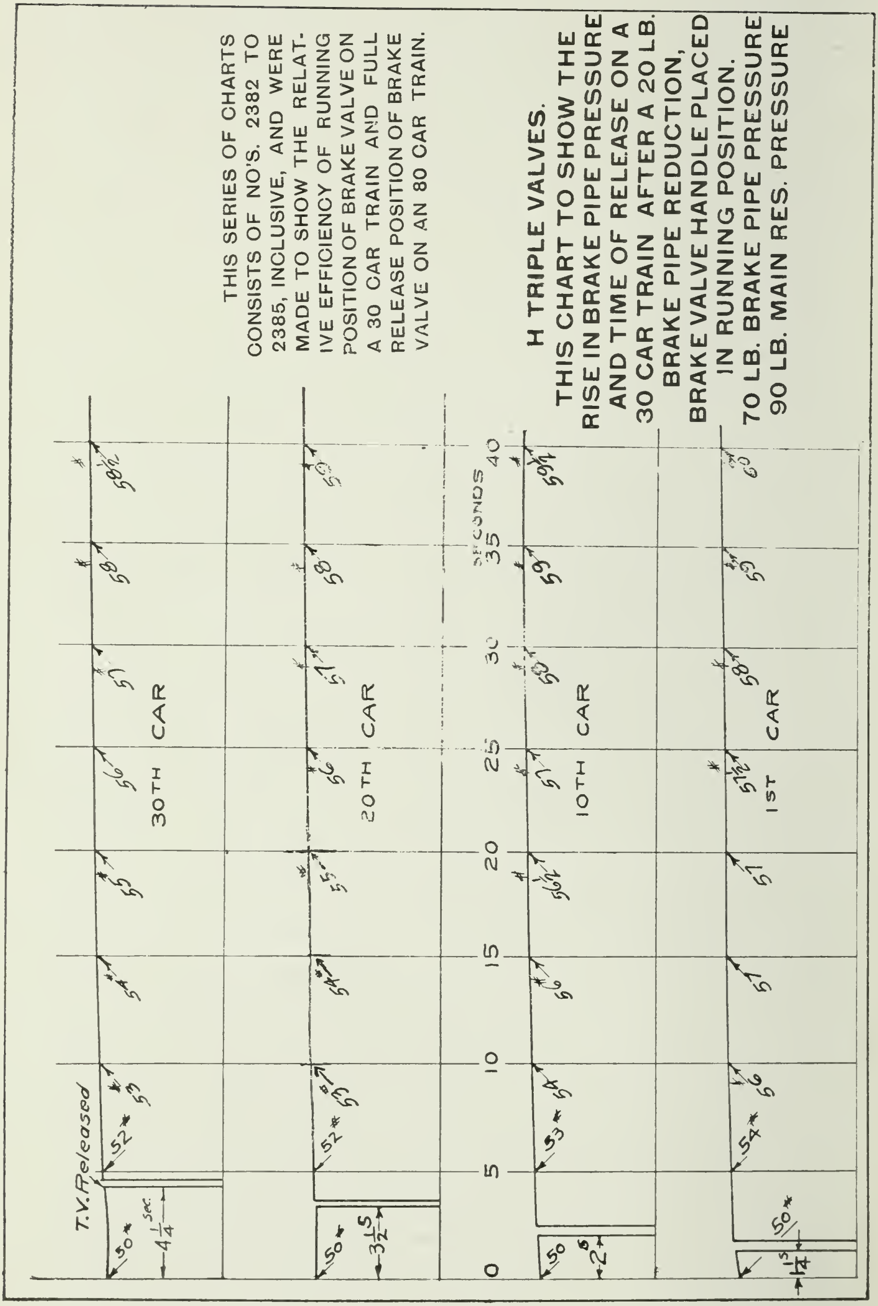
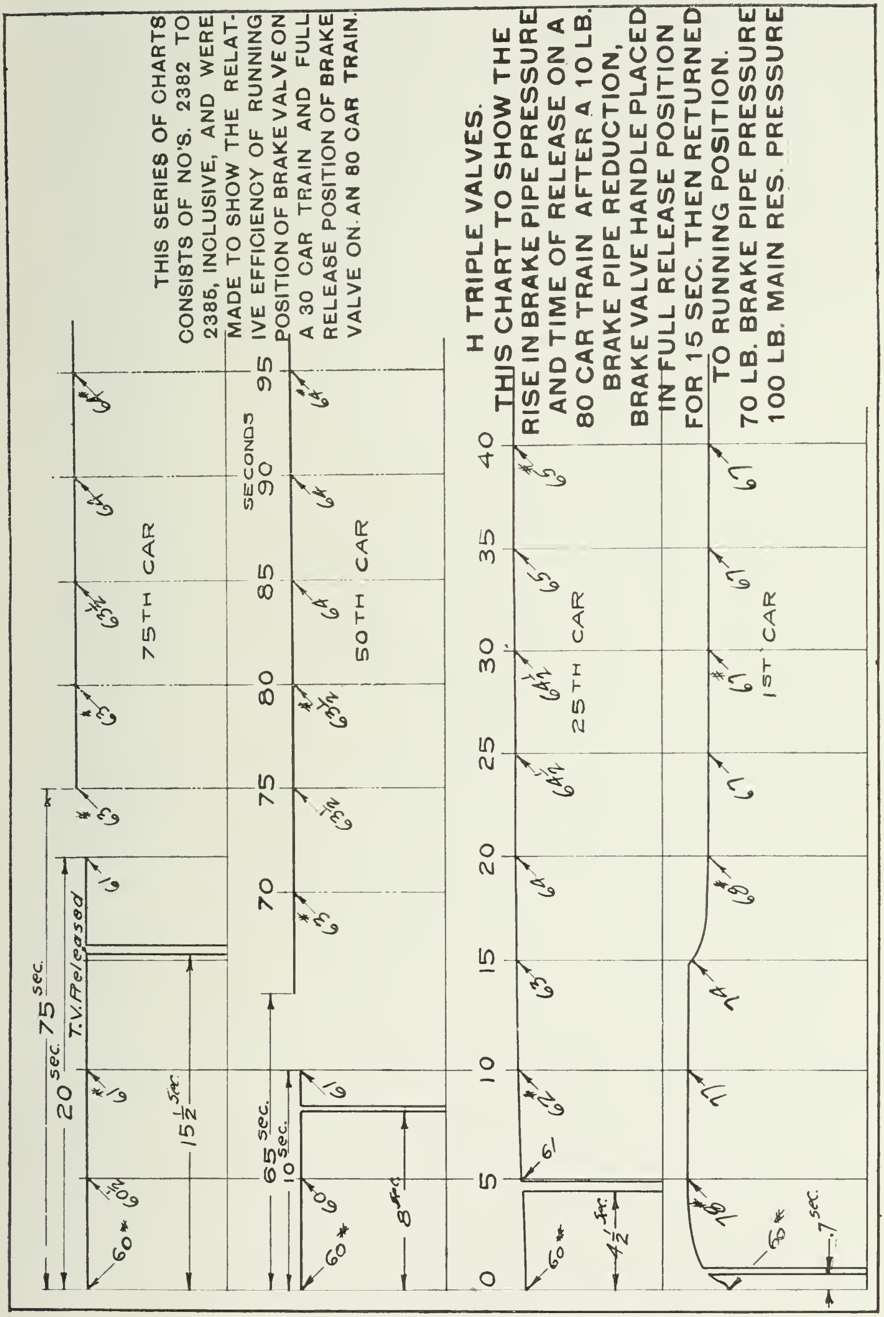

THIS SERIES OF CHARTS CONSISTS OF NO'S. 2382 TO 2385, INCLUSIVE, AND WERE MADE TO SHOW THE RELATIVE EFFICIENCY OF RUNNING POSITION OF BRAKE VALVE ON A 30 CAR TRAIN AND FULL RELEASE POSITION OF BRAKE VALVE ON AN 80 CAR TRAIN.
H TRIPLE VALVES.
THIS CHART TO SHOW THE RISE IN BRAKE PIPE PRESSURE AND TIME OF RELEASE ON A 30 CAR TRAIN AFTER A 20 LB. BRAKE PIPE REDUCTION, BRAKE VALVE HANDLE PLACED IN RUNNING POSITION.
70 LB. BRAKE PIPE PRESSURE
90 LB. MAIN RES. PRESSURE
T.V. Released
30TH CAR
20TH CAR
10TH CAR
1ST CAR
SECONDS
0
5
10
15
20
25
30
35
40

Fig. 22.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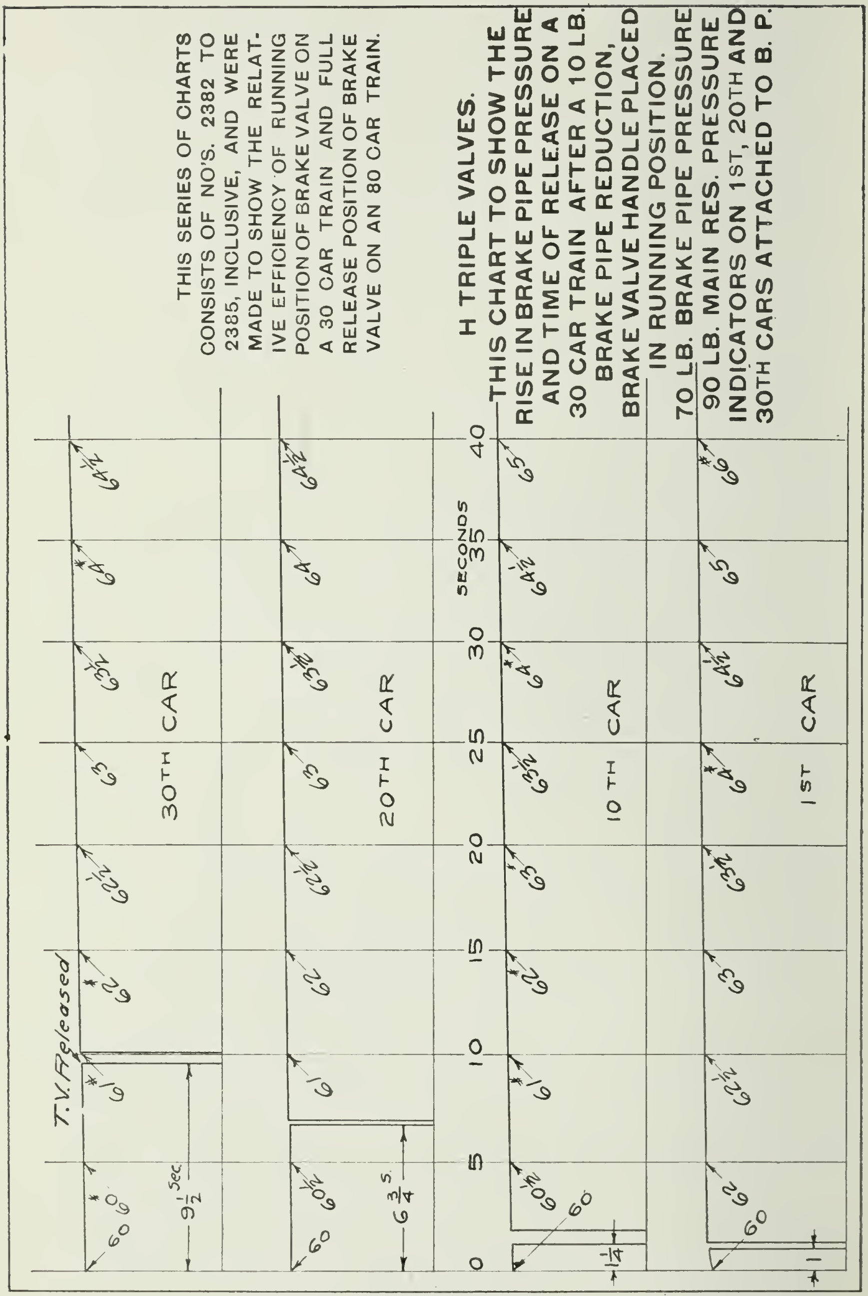
H TRIPLE VALVES.
THIS CHART TO SHOW THE RISE IN BRAKE PIPE PRESSURE AND TIME OF RELEASE ON A 80 CAR TRAIN AFTER A 10 LB. BRAKE PIPE REDUCTION, BRAKE VALVE HANDLE PLACED IN FULL RELEASE POSITION FOR 15 SEC. THEN RETURNED TO RUNNING POSITION.
70 LB. BRAKE PIPE PRESSURE
100 LB. MAIN RES. PRESSURE
75TH CAR
50TH CAR
25TH CAR
1ST CAR
SECONDS
0 5 10 15 20 25 30 35 40
70 75 80 85 90 95
T.V. Released
20 sec.
75 sec.
65 sec.
10 sec.

FIG. 23.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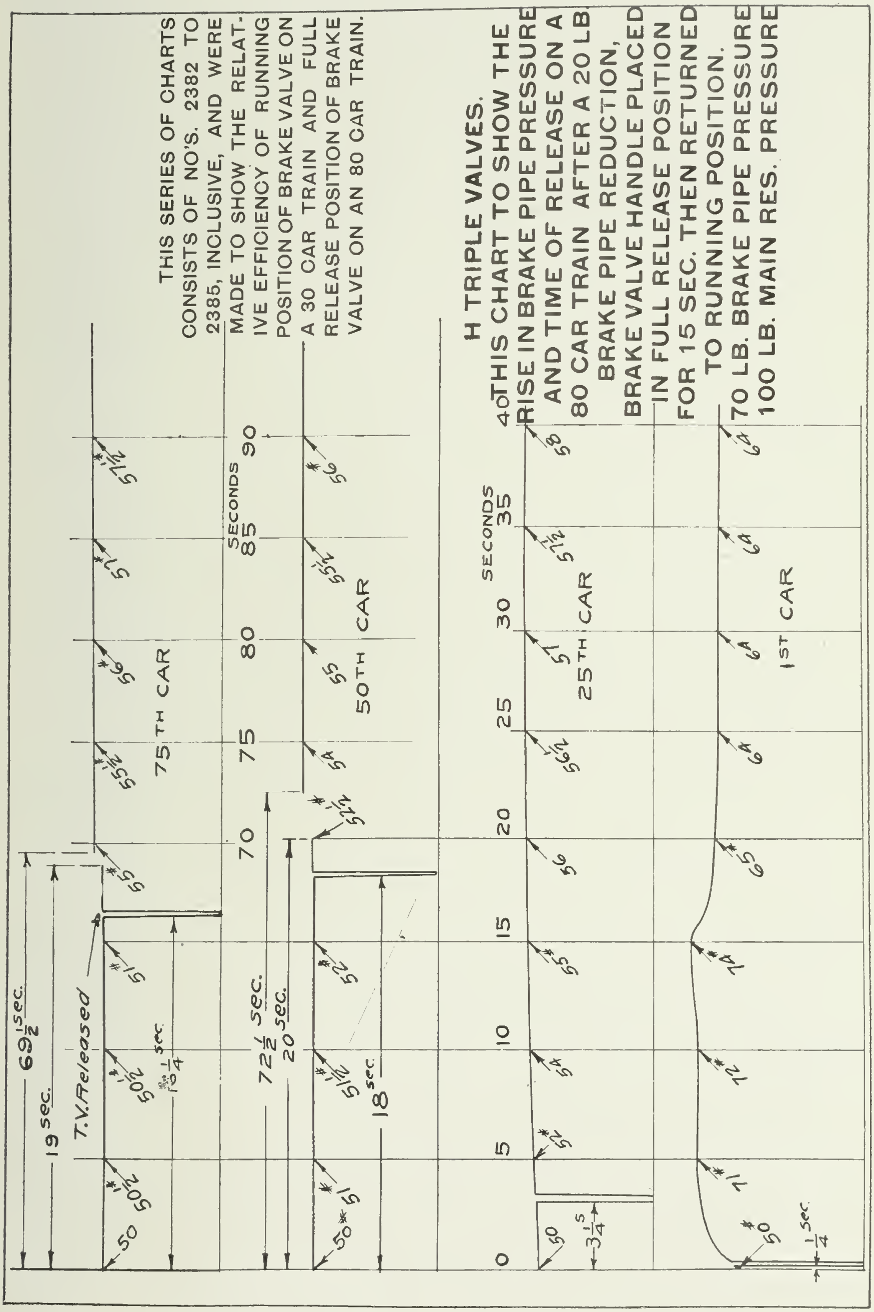
H TRIPLE VALVES.
THIS CHART TO SHOW THE RISE IN BRAKE PIPE PRESSURE AND TIME OF RELEASE ON A 30 CAR TRAIN AFTER A 10 LB. BRAKE PIPE REDUCTION, BRAKE VALVE HANDLE PLACED IN RUNNING POSITION.
70 LB. BRAKE PIPE PRESSURE
90 LB. MAIN RES. PRESSURE
INDICATORS ON 1ST, 20TH AND 30TH CARS ATTACHED TO B. P.
SECONDS
0 5 10 15 20 25 30 35 40
T.V. Released
30TH CAR
20TH CAR
10TH CAR
1ST CAR
9½ Sec.
6¾ S.
1¼
1

FIG. 24.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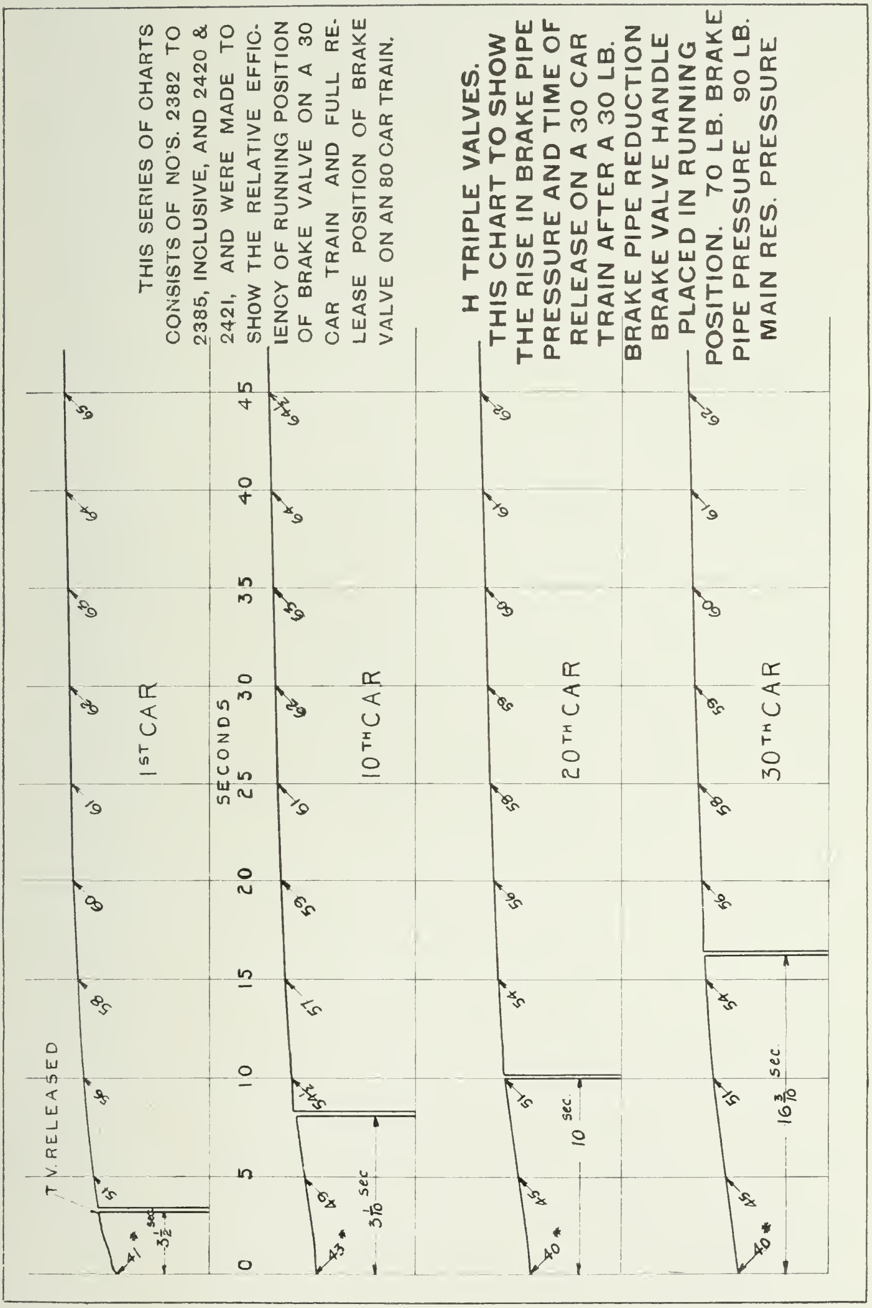
H TRIPLE VALVES.
THIS CHART TO SHOW THE RISE IN BRAKE PIPE PRESSURE AND TIME OF RELEASE ON A 80 CAR TRAIN AFTER A 20 LB. BRAKE PIPE REDUCTION, BRAKE VALVE HANDLE PLACED IN FULL RELEASE POSITION FOR 15 SEC. THEN RETURNED TO RUNNING POSITION.
70 LB. BRAKE PIPE PRESSURE
100 LB. MAIN RES. PRESSURE
75TH CAR
50TH CAR
25TH CAR
1ST CAR
SECONDS
T.V. Released
69½ sec.
19 sec.
72½ sec.
20 sec.
18 sec.

FIG. 25.

Figs. 26 and 27. These charts are similar to those preceding, except that the brake pipe pressure has been reduced below the equalizing point. This is an operation that is very likely to be prolific of damage, particularly break-in-twos, as it is not difficult to raise the brake pipe pressure up to that of the auxiliary reservoirs at the head end of the train, but it is impossible to raise the brake pipe pressure at anywhere near the same rate at the rear of the train, consequently, there is much greater interval of time between the release of the forward brakes and the rear brakes than where the brake pipe pressure has not been reduced below that of the auxiliary reservoir. In fact, so long as an interval exists that the engineer is very likely to help the retardation still going on on the rear, break the train in two by opening the throttle, if the train is still running and, if standing, by starting the forward end of the train before the brakes have released at the rear. After the brake pipe pressure has by any means fallen below that of the auxiliary reservoir a very long period of time, comparatively, must elapse before the brakes will release at the rear end of the train. This is apparent from an inspection at the rate of rise of brake pipe pressure, as shown on the charts, which is not more than 8 pounds per minute after the forward triple valves have gone to release position; consequently if the brake pipe has been reduced 10 pounds below that of the auxiliary reservoir about 1 minute must elapse before it is certain that the brakes have released.

A glance at Fig. 27 will show that after such an over reduction that part of the train ahead of the 25th car was running free before even the 50th car had started to release.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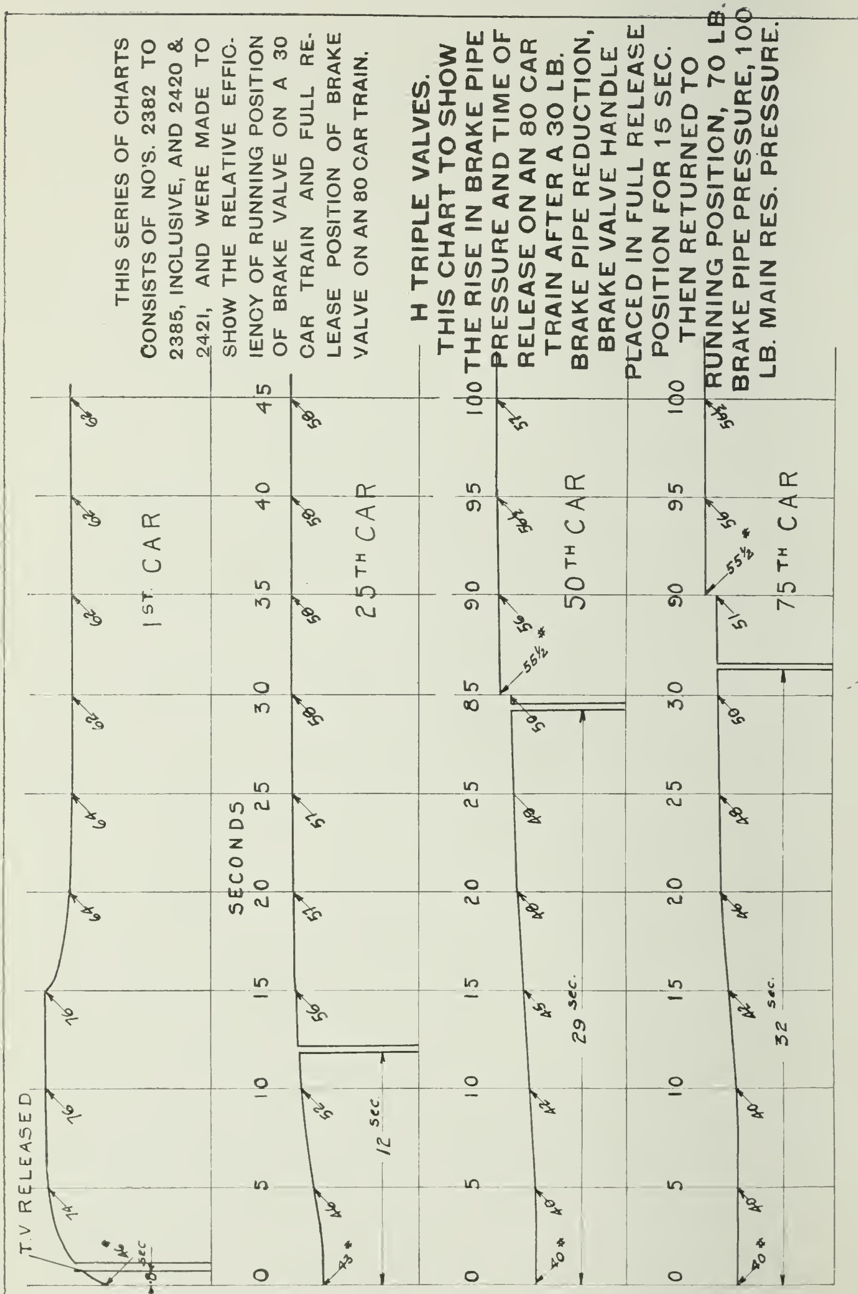
H TRIPLE VALVES.
THIS CHART TO SHOW THE RISE IN BRAKE PIPE PRESSURE AND TIME OF RELEASE ON A 30 CAR TRAIN AFTER A 30 LB. BRAKE PIPE REDUCTION
BRAKE VALVE HANDLE PLACED IN RUNNING POSITION. 70 LB. BRAKE PIPE PRESSURE 90 LB. MAIN RES. PRESSURE
T.V. RELEASED
SECONDS
0 5 10 15 20 25 30 35 40 45
1ST CAR
10TH CAR
20TH CAR
30TH CAR
3½ sec
3 1/10 sec
10 sec
16 3/10 sec

Fig. 26.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T.V RELEASED
1ST CAR
SECONDS
25TH CAR
12 sec
50TH CAR
29 sec
75TH CAR
32 sec

FIG. 27.